January 2002 USACHPPM Technical Guide 230

Chemical Exposure Guidelines for Deployed Military Personnel

U.S. Army Center for Health Promotion and Preventive Medicine

PREFACE

In line with various Department of Defense Instructions (DODIs), Headquarters Department of the Army (HQDA) Letter 1-01-1 (2001) *Force Health Protection (FHP): Occupational and Environmental Health (OEH) Threats* establishes responsibilities that direct commanders to use the operational risk management (ORM) process to manage Force Health Protection – Occupational and Environmental Hazards (FHP-OEH) and to minimize total [health and safety] risk to personnel across the broad spectrum of military operations. This includes identifying, documenting, and reporting exposures to OEH hazards (e.g., chemical) that may result in short- or long-term health effects to deployed military personnel.

This document combines and supersedes TG 230A, *Short-Term Chemical Exposure Guidelines for Deployed Military Personnel* (May 1999), and TG 230B, *Draft Long-Term Exposure Guidelines for Deployed Military Personnel* (May 2000). This TG provides the most current military guidance for assessing chemical hazards during deployments in line with existing ORM doctrine.

Additional Information, Updates, and Revisions

Chemical hazard risk assessments for deployments have been performed on a regular basis since 1995 by the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) as well as other service organizations. The USACHPPM approach to characterizing chemical-related risks has evolved over the past several years. Our goal has been to learn through experience and establish a standardized, supportable methodology that will ultimately be applied directly "in the field" by appropriate military medical/health personnel.

USACHPPM has also assisted the Army Medical Department (AMEDD) Center and School in incorporating a session on TG 230 in the basic 6AF5 course for new Army medical and preventive medicine officers. As such, it is reasonable to expect a growing awareness and understanding of this guide and its use. In addition to the basic guidance the USACHPPM is continuing associated efforts to facilitate consistent assessment of chemical hazards. One such effort is to establish chemical-specific summary information called Chemical Hazard Information for Deployments (CHIDs). Each of these sheets will summarize a variety of physical, chemical, toxicological, medical and detection information not available in the TG 230. The USACHPPM is developing CHIDs on a case-by-case basis for chemicals often detected or for which specific information has been requested. Finally, one of our major initiatives during 2002 will be the development of a software program that will guide the user through the TG 230 process, assisting in summarizing data and addressing unique issues associated with various chemical hazards to produce a standardized ORM Deployment Chemical Risk Assessment Summary Report. We are hoping to have this available from our website by 2003.

This TG and its supporting Reference Document (RD 230, USACHPPM 2001) present our current methodology. Due to scientific advances and expanding operational needs, our methods and documents will be updated as necessary. Users should ensure that they have the most up-to-date version of TG 230 and any supporting reference materials and guidance. This document and associated information (to include information regarding past and present deployment support assessments such as for deployment operations in Bosnia, Kosovo, and Kuwait) can be obtained electronically from the following website:

http://chppm-www.apgea.army.mil/desp/pages/samp_doc.htm

Questions, comments, and recommendations can also be forwarded to USACHPPM:

US Army Center for Health Promotion and Preventive Medicine
Deployment Environmental Surveillance Program
ATTN: MCHB-TS-EES
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SECTION 1

INTRODUCTION

1.1 PURPOSE

> Everyday as we respond to the nation's needs, we expose our soldiers to hazards in uncertain and complex environments. We do this with the full knowledge that there are inherent risks associated with any military operation. The nature of our profession will not allow for either complacency or a cavalier acceptance of risk.
>
> —General D.J. Reimer, Chief of Staff Army (DA 1998)

Technical Guide 230 (TG 230) provides military exposure guidelines (MEGs) for chemicals in air, water, and soil for use during deployments. Specific information is provided regarding the type and severity of health effects resulting from exposures to varying chemical concentrations, the primary organs/systems affected, odor /taste threshold information, and additional notes when available. Perhaps more importantly, this TG provides application guidance describing how the MEGs can be used to characterize the level of health and mission risks associated with identified or anticipated exposures to chemicals in the deployment environment in a manner consistent with the existing military Operational Risk Management (ORM) paradigm. The intent is that trained personnel such as preventive medicine officers, environmental staff officers, industrial hygienists, health risk assessors, or other medically trained personnel, can use this guide to consistently characterize risks from chemical exposures by use of a standardized process that is both scientifically supportable and militarily feasible. This TG is not designed for typical garrison operations, as these are covered under existing Department of the Army (DA) occupational health and environmental compliance regulations. However there is limited application in catastrophic continental United States (CONUS) scenarios (i.e., terrorist events). Further details are included in Sections 1.1.2 and 1.4 discussing the intended applications. For the convenience of the reader, Appendix A presents the references used in this TG and Appendix B provides a glossary and list of acronyms.

1.1.1 Key Assumptions and Decisions

Developing this guidance required several up-front risk management decisions that cannot be answered definitively by science. To the extent possible, these reflect existing military policy/ directives, but some issues are not adequately determined by current policy or regulation. The key decisions/assumptions used in the preparation of this document include:

- Whether health effects caused by chemical exposures during a deployment are immediate or delayed (even delayed for several years), the risk of *any* adverse health effect is to be considered in military operations. However, since military ORM focuses on success of the current mission, the guidance presented in this TG is based on the decision that health effects that have immediate impacts and affect personnel functional capabilities are of greater concern than delayed health effects (e.g., increased risk of cancer).

- The military population, for which these guidelines are developed, is assumed to be "healthy and fit" and often believed to be less susceptible to the adverse health effects caused by chemical exposures than the general (civilian) population. However, this assumption has been debated and an assessment of susceptibility traits amongst the military population concluded that for many health effects the military population is of equivalent variability as the general population (see section 2.4). There are known and unknown subpopulations within the deployed military population that may be uniquely susceptible to effects caused by certain chemicals. In some cases where adequate information was available, the MEGs accommodate a susceptible group within the military population (e.g., asthmatics, who are included in deployment operations). Although pregnant women are not considered deployable, there are potential scenarios where a woman may be deployed without realizing her pregnant status. Since developmental effects caused by chemical exposures are often associated with first trimester exposures, and since the fetus is considered a *third party* involuntarily being put at risk, legal and ethical recommendations have resulted in these guidelines to be protective against developmental effects where such data was available. As a result, several MEGs are the same as would be applied to a civilian population. However, the MEGs have been screened to ensure that they are not based on health effects that are clearly not associated with deployed military personnel (i.e. they are not designed to protect people that would never be deployed such as children or the elderly).

- Current scientific methods for deriving human health guidelines focus on estimating human threshold concentrations by using toxicological data along with safety factors to account for various data gaps and uncertainties. The resulting MEGs in this TG represent conservative *population thresholds* for different types of health effects. This provides the user with an idea of when the specified effect may begin to be noticed in a small percentage of the exposed persons. It does *not* represent levels at which the majority, median, or 50% of personnel will demonstrate such effects as the selected scientific models do not provide this information.

1.1.2 Scope

This version of TG 230 is a combined and updated version of TG 230A and TG 230B (see Preface). The associated Reference Document (RD 230) has also been completed to support the material herein. Specific technical material has been limited in this TG to facilitate field use. RD 230 provides the technical information that support the derivation of the MEG values and other information contained herein.

This TG does not address biological or nuclear/radiation hazards. Its focus is on chemical hazards – both chemical warfare agents (CWAs) as well as toxic industrial chemicals (TICs). However, there are limitations in this TG regarding chemical hazards:

- Not every chemical is listed (see section 1.4.1) since many chemicals have limited toxicity information available. TG 230 has focused on chemicals with readily available information or which were otherwise identified as key hazards of concern. Future amendments to TG 230 will include both updated MEGs as well as the addition of chemicals.

- Other aspects critical to addressing occupational and environmental health (OEH) chemical hazards include guidance on sampling contaminated media, control methods, and medical treatment. While these topics are beyond the scope of this TG, additional guidance in these areas is currently being developed by USACHPPM in the form of Chemical Hazard

Information for Deployments (CHIDs) (see Preface) as well as other guidance (see the back cover).

✍✍The purpose of the MEGs is to provide protection to our personnel from chemical exposures during deployments. The MEGs are not designed for environmental compliance purposes and should not be used as environmental compliance/preservation/remediation goals in CONUS or outside the continental United States (OCONUS).

1.2 BACKGROUND

> Risk Management is not an add-on feature to the decision-making process but rather a fully integrated element of planning and executing operations… Risk management helps us preserve combat power and retain the flexibility for bold decisive action. Proper risk management is a combat multiplier that we can ill afford to squander.
>
> —General D.J. Reimer, 1995 (DA 1998)

1.2.1 Health and Operational Hazards

The deployed military population is subject to a variety of operation-related hazards. These hazards include climate conditions (e.g., excessive heat, cold and noise), infectious diseases, physical threats (including those associated with accidents, explosions, and certain forms of ionizing radiation), chemical and biological warfare agents, and a large number of chemical contaminants in air, water, food, and soil. Forces might be exposed to these hazards intermittently, continuously, or simultaneously. Exposures to chemicals during deployments and other operations are inevitable. In some situations chemicals may be present for only a short time, but at high enough levels that exposures could immediately impact individual health or even degrade the mission. In other situations, continuous but less extreme levels of chemicals in the environment could put military personnel at increased risk of delayed, permanent health problems.

1.2.2 Health Risk Management Policies and Procedures

The military, scientific, and political communities have recently acknowledged the need to identify and consider (as identifiable military "threats") all toxic chemicals or radiological hazards that pose delayed, chronic health risks to military personnel (IOM 1999, NRC 1999, DOD 1999, DODI 6055.1, and NSTC/PRD 5). Military leaders and their staff elements are now responsible for monitoring, assessing, and minimizing OEH hazards to ensure force health protection. A listing of policies, procedures, and guiding principles for the management of such hazards are listed in RD 230.

Deployment scenarios can involve a range of operations from sustaining peace and stability to direct combat. While the hazards may be of a different nature during these operations, the hazard management process is the same. This process requires the identification of hazards, a standardized categorization of the risks, and a decision process that appropriately balances these risks to minimize adverse impacts on the mission and personnel. Field Manual (FM) 100-14, *Risk Management* and FM-3-100.12, *Risk Management: Multiservice Tactics, Techniques, and Procedures* provide the ORM doctrine that defines this process. Making decisions to accept, minimize, or altogether prevent OEH hazards must be made in conjunction with assessments of other operational hazards that put the commander's mission and personnel at risk.

It is DOD and Army policy to address the health and mission risks associated with chemical exposures within the overall ORM process (DODI 6055.1 and HQDA Letter 1-01-1). Specifically, appropriate consideration of OEH chemical hazards are a part of Force Health Protection (FHP), and proper assessment and surveillance should be used to minimize both immediate health and mission impacts, as

well as any potential delayed health effects that adversely effect the long-term health of service men and women. The objective is to minimize overall health risks while achieving successful mission completion. This will always be a balance. War-time operations will inevitably yield higher acceptance of casualties, while peacekeeping missions will require greater need to minimize non-severe health effects associated with what has been referred to as "low-level" exposures. Low-level exposures are those that may not significantly impact the current mission or result in any function-impairing effects, but which constitute an exposure that could have a health effect. Further discussion on different levels of health effects and associated mission impacts are discussed in Section 3 and presented in Table 3-1.

TG 248, *Guide for Deployed Military Personnel on Health Risk Management*, (USACHPPM 2001) provides a general framework for addressing OEH hazards (i.e., chemical, radiological, biological, entomological, endemic disease) in a way that implements the established ORM process, as defined by FM 100-14. This revised TG 230 was developed following the framework used in TG 248. Appropriate application of ORM and this TG will allow appropriate consideration be given to chemical hazards. The use of MEGs within the TG 248 ORM process is presented in Section 3.

1.3 AUDIENCE

> Staff members continuously look for hazards associated with their area of expertise. They then recommend controls to reduce those risks…. Leaders, staff and soldiers become the assessors for ever-changing hazards such as those associated with the environment (weather, visibility, contaminated air, soil, water), equipment readiness, unit experience, and fatigue. Leaders and staff should advise the chain of command on risks and risk reduction methods.
>
> —FM 100-14, Risk Management

TG 230 is designed to assist trained preventive medicine/medical personnel in the evaluation of chemical exposure data in order to minimize health and mission risks during deployments. These trained personnel are to use the TG as an objective base from which to make educated determinations. It is not intended for use by untrained personnel or as a substitute for having trained preventive medicine personnel onsite or in theater. Users should have a basic understanding of the underlying toxicological/health basis for these guidelines. They should be familiar with basic methods of exposure assessment of chemicals in the environment. Finally, it is necessary that the user appreciate the uncertainties associated with sampling and with the assumptions used for estimating representative exposure levels. Military health services personnel will need to use professional judgment when applying the standardized information in this guide; however, they will be more adequately prepared to determine the severity of health hazards within a framework that is consistent with other military risk management decisions.

1.4 APPLICATION AND LIMITATIONS OF USE

> First reckon, then risk.
>
> —Field Marshal Helmuth von Moltke, FM 100-14, Risk Management (DA 1998)

> Risk Management is the recognition that decision-making occurs under conditions of uncertainty… —FM 100-14, Risk Management (DA 1998)

In general, this TG should be used to characterize health and medical threats and the risks they pose to personnel and the mission. The user should compare the guidelines with field sampling data or other (e.g., modeled) exposure data information. The interpretation of these comparisons will require professional judgment. Due to the uncertainties that are inherent in the toxicological data, as well as the variations in human response to chemical exposure and the exposure estimates that go into establishing health-based guidelines, users should not use the MEGs as strict, bright-lines (i.e., go/no-go standards) for decision making unless so noted (e.g., water MEGs based on TB MED 577). Instead, the TG and its range of MEGs provide a set of criteria that are to be used to identify and rank OEH risks from chemical exposures in a deployment setting. The range of concentration levels and exposure durations represented for each chemical are designed to give the user an idea of the overall toxicity and types of health effects associated with certain exposure scenarios. MEGs range from high levels that represent a "threshold" for fatality to levels that could be present continuously for short or long-term periods without resulting in any significant symptoms.

1.4.1 Use in Different Types of Deployment Scenarios

For certain types of deployment operations (such as direct combat), it is anticipated that such guidelines will be of limited importance to the overall ORM decision-making process. That is, "physical" hazards such as armed adversaries will present much greater risks and, therefore, be of greater priority. For other scenarios, such as long-term humanitarian deployment operations, the considerations of overall long-term personnel health may play a more critical role in risk management decisions. Accordingly, these guidelines are to be used at the discretion of the commander. As stated in the HQDA Letter 1-01-1 (2001) *Force Health Protection (FHP): Occupational and Environmental Health (OEH) Threats*:

> "…commanders [need to be] aware of and consider risks created by OEH exposures (both long-term and short-term) during all phases of military activities…[and]…reduce OEH exposures to as low as practicable to minimize short- and long-term health effects in personnel within the context of the full spectrum of health and safety risks confronting the deployed personnel."

1.4.2 Other Technical Guidance Pertaining to Chemical Hazards

To the extent possible, a wide variety of occupational, environmental, and military standards have been considered and incorporated into the development of these guidelines. There is a substantial amount of technical information on various chemicals that can be obtained from other sources (hardcopy or electronically such as through the internet). To the extent that personnel have the resources, accessibility, and time to review additional information, this is encouraged as it will likely increase overall confidence in the assessment and characterization of risk. However, it is anticipated that there will be situations where there are inconsistencies in information or guideline levels. To the extent possible, RD 230 delineates in detail the basis for the MEGs and in many cases describes reasons for conflicts with other standards. Where such explanations are not available, the user must use professional judgment or contact USACHPPM for consultation. When assessing industrial-type operations during deployments, where the soldiers' activities involve typical 8-hour workday situations (e.g., motor pool maintenance), existing industrial hygiene standards may be more appropriate than MEGs.

1.4.3 Use with Caution: Scientific Uncertainties

Uncertainties involved in the development of these guidelines are principally those related to exposure parameters and toxicological data. Uncertainties in the toxicological data may result from data gaps, insufficient quality or quantity of data, and/or lack of human data. Exposure assumptions used in developing these guidelines include inhalation and ingestion rates, body weights, and frequency and duration of exposure. These assumptions may or may not represent those in actual deployment scenarios.

Furthermore, the environmental levels estimated through sampling are often not likely to remain constant. The user must consider these uncertainties when making risk management decisions or recommendations.

Use of this TG should not be construed as a "definitive quantification of health outcomes." In most deployment scenarios, it will be difficult to make definitive statements as to the absolute degree of risk/type of health effect(s) caused by environmental contaminants. Even statements regarding whether a risk is present or not must be carefully stated to ensure that the uncertainty inherent to any risk assessment is accurately considered and weighed.

In addition to communicating a level of risk associated with a chemical hazard, a user should be prepared to describe the degree of confidence in his/her assessment (such as high, moderate, or low confidence). An estimate of a "high" risk that has low confidence (i.e., uncertainty is high) may significantly influence Command decisions, especially if there are other high risks for which there is greater levels of certainty. Guidance for determining confidence levels is provided in Section 3.3.

Due to limitations in toxicity data, the nature of chemical exposures and human variability, OEH chemical risk assessments should almost never be ranked with high confidence. For the most part, the MEGs are conservatively designed so that confidence in estimated *Low Risks* will tend to be greater than those estimated to be *High Risk*.

1.4.4 Chemical Not Listed in these Guidelines

Though the list of chemicals included in this TG is quite broad, there are occasions where identified chemicals will not have a specified guideline. In general, this may be because there is limited toxicity information available for the chemical. Occasionally, there may be a short-term guideline but no long-term guideline for a chemical. In these cases, it is likely that the chemical poses primarily an acute (short-term) hazard at higher concentrations but at lower concentrations there are no documented effects, even after continued long-term exposures. On the other hand, some chemicals may not pose a health risk unless the exposure is constant and repeated over a long-term exposure. In this case, there may not be any short-term MEGs.

In any situation where there is information lacking on a chemical, the user has a few options: (1) contact USACHPPM to do research and characterize severity and risk; (2) establish an overall risk estimate based on other chemicals and information in this TG and document the uncertainty (i.e., reduced confidence) in the risk estimate by not including a chemical assessment of the chemical(s) with no MEGs; or (3) research the chemical (e.g., literature or internet resources) and establish a surrogate guideline.

Key reference sites for looking up additional chemical information are prioritized below. When using values/data from these sites the user should attempt to be consistent with the MEG derivations/guidelines presented in RD 230.

- http://toxnet.nlm.nih.gov/
- http://www.cdc.gov/niosh/npg/npg.html
- http://www.epa.gov/region09/waste/sfund/prg/index.htm

1.4.4.1 "Non-Hazards". Some chemical data received from routine laboratory analyses will include certain chemicals/ constituents/compounds that can be readily identified as "non-hazards". These are primarily identified in soil or water analysis and include essential nutrients, minerals, and related compounds. They are found commonly in nature and are considered, at least at some level, beneficial or even necessary to the proper functioning of the human body.

Soil: If identified in laboratory results, the following are examples of constituents that can generally be considered as non-hazards and do not need to be factored into a health risk assessment. These constituents are generally only toxic when ingested in large amounts at high concentrations, which is not realistically feasible from soil ingestion at typical environmental concentrations. For these reasons, many of these constituents lack Federal guidance as well.

TABLE 1-1. TYPICAL NON-HAZARDOUS CONSTITUENTS DETECTED IN SOIL

Aluminum	Barium	Magnesium	Potassium	Sodium
Calcium	Iron	Manganese	Selenium	

Drinking Water: Drinking water analysis also often includes constituents that may not cause adverse health effects, but which may aesthetically (e.g., color, taste, odor) make the water less palatable. This could lead to reduced consumption that could in turn result in indirect health effects from dehydration (Case Study 4 in Appendix F provides an example scenario). In addition, these criteria may be a useful source of information when evaluating water treatment system capabilities. While there are guidelines and standards (per TB MED 577) to ensure that aesthetic standards are met – it is useful to note that these guidelines/criteria are not based on direct toxic health effects. Tables 1-2 and 1-3 summarize various aesthetic factors considered in assessing drinking water.

TABLES 1-2 AND 1-3. AESTHETIC FACTORS IN ASSESSING DRINKING WATER

Table 1-2. Physical Properties	**Maximum level 5-15L/day (TB Med 577)**	
	<7 days	>7 days
Color (color unit)	50	15
Odor (TON)	3	3
pH	5-9	5-9
TDS (mg/L)	1000	1000
Turbidity (NTU)	1	1

Table 1-3. Chemical Properties	**Recommended maximum level (U.S. EPA*)**
Aluminum	0.05 – 0.2 mg/L
Fluoride	2 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Silver	0.1 mg/L
Sulfate	250 mg/L

* U.S. EPA public drinking water criteria are recommendations only.

SECTION 2

MILITARY EXPOSURE GUIDELINES

2.1 WHAT ARE MEGs?

MEGs are concentrations for chemicals in air, water, and soil that can be used to assist in assessing the significance of field exposures to OEH chemical hazards during deployments. TG 230 MEGs are designed to address a variety of scenarios such as a single catastrophic release of large amounts of a chemical, temporary exposure conditions lasting hours to days, or for continuous ambient environmental conditions such as regional pollution, use of a contaminated water supply, or persistent soil contamination where there is regular contact. For each environmental media there are slightly different exposure scenarios of concern.

Specifically, a MEG is a chemical concentration which represents an estimate of the level above which certain types of health effects may begin to occur in individuals within the exposed population after a continuous, single exposure of specified duration. The severity of the health effects and percentage of the exposed population demonstrating health effects will increase as concentrations increase above the MEG, but the rate is chemical-specific, and therefore cannot be represented by the MEGs themselves. The MEGs are not designed for determining casualty estimates but are instead are preventive measures guidelines.

Since existing toxicological databases were utilized, the quality and extensiveness of toxicological information underlying these guidelines is comparable, and as variable, as that used by Federal agencies for worker and civilian applications. For specific details on the various approaches and methods used to develop the guideline values, refer to RD 230.

2.1.1 Air-MEGs: Inhalation of Chemicals

Table 2-1 defines the types of Air-MEGs and the meaning behind exceedences of the various air guidelines. Air-MEGs are presented in Appendix C.

In deployment situations, the most prominent and likely exposure pathway for exposure to chemicals is through the inhalation of contaminated air. As contaminants in air are difficult to avoid or control and may produce immediate and severe health effects, a variety of Air-MEGs were developed. Some of these levels represent severe conditions that are likely to have real-time, direct impacts on personnel performance and mission accomplishment/success. For selected CWAs, Air-MEGs are provided for temporary and short-term exposure scenarios of 10 minutes, 1 hour, 8 hours, and 24 hours (Table C-1). For other airborne chemicals, Air-MEGs for short-term exposure scenarios of 1 hour, 8 hours, and 14 days are provided (Table C-2). Air-MEGs are also provided for 1-year (deployment-length), continuous exposures (Table C-3). Guidelines for priority pollutants are provided in Table C-4.

TABLE 2-1. DEFINITIONS OF HEALTH EFFECTS ASSOCIATED WITH AIR-MEGS

EXPOSURE DURATION		HEALTH EFFECTS AND PERFORMANCE DEGRADATION *
SHORT-TERM	1-hour	The airborne concentration above which continuous exposure for 1 hour could begin to produce life-threatening or lethal effects in a small portion of individuals. Increasing concentrations and/or duration of exposure will increase incidence of lethality and severity of non-lethal severe effects.
	1-hour	The airborne concentration above which continuous exposure for 1 hour could begin to produce irreversible, permanent, or serious health effects that may result in performance degradation and incapacitate in a small portion of individuals. Increasing concentrations and/or duration of exposure will increase incidence and severity of effects.
	1-hour	The airborne concentration above which continuous exposure for 1 hour could begin to produce mild, non-disabling, transient, reversible effects, if any. Such effects should not impair performance. Increasing concentration and/or duration could result in performance degradation, especially for tasks requiring specific mental/visual acuity or physical dexterity/strength.
	8-hour and 24-hour **	The airborne concentration above which continuous exposure for 8 or 24 hours could begin to produce mild, non-disabling, transient, reversible effects, if any. Such effects should not impair performance. Increasing concentration and/or duration could result in performance degradation, especially for tasks requiring specific mental/visual acuity or physical dexterity/strength.
	14-day	The airborne concentration for a continuous exposure for up to 14 days (24 hours/day) that should not impair performance and is considered protective against significant, non-cancer effects. Increasing concentration and/or duration could result in performance degradation or increase the potential for inducing delayed/permanent disease (e.g., kidney disease or cancer).
LONG-TERM	1 year	The airborne concentration for a continuous exposure up to 1 year (365 days, 24 hours/day) that is considered protective against health effects including chronic disease and increased risk to cancer (i.e., cancer risk greater than 1×10^{-4}). No performance degradation or long-term health consequences are expected with exposure at or below this level. Increasing concentration and/or duration could increase the potential for delayed/permanent disease (e.g., kidney disease or cancer).

* Sensitive individuals may be predisposed to toxic effects and, therefore, maybe more susceptible. If available scientific evidence regarding such subpopulations exists for a particular chemical, then this information is provided in the guideline tables.

** For military unique chemicals warfare agents (i.e., GA, GB, GD, GF, VX, and HD), a 24-hour MEG has been derived instead of a 14-day MEG because of the likelihood for CWA exposures to extend beyond a 24-hour period is extremely small. The 24-hour CWA MEGs are described in detail in Table C-1. The definition of effects associated with these values is the same as the 8-hour guidelines.

2.1.2 Water-MEGs: Chemicals Ingested in Potable Water

Table 2-2 defines the types of Water-MEGs and the meaning behind their exceedence. Water-MEGs are presented in Appendix D – Table D-1 for short-term exposure scenarios of 5 days and 2 weeks and Table D-2 for 1-year (deployment-length) continuous exposures.

Potable water implies various uses; however, these guidelines reflect the specific exposure pathway of direct consumption of a water source. Applying such guidelines to make decisions regarding bathing, teeth brushing, dishwashing, or other non-potable water applications are over-conservative applications, but at this time no other guidelines have been derived for these specific scenarios.

Water-MEGs are based on specific exposure conditions that are described by daily rates of water consumption that have been designated as typical standards for military deployment operations: 5 liters (L)/day for moderate climates and 15 L/day in dry/arid climates. These rates are extremely high in comparison to typical general population drinking /consumption rates (e.g., 2L/day) but these rates have been validated and established in Army doctrine (TB MED 577). The Water-MEGs are designed to indicate "thresholds" for minimal to no adverse health effects. The health effects at these levels do not generally represent observable degradation in personnel performance. However, the more chemical concentrations in a water source exceed a guideline level or the duration of exposure, the more likely that a greater portion of those exposed will develop symptoms of exposure. When available, information regarding levels that produce severe or lethal effects is also provided in the Appendix D tables.

TABLE 2-2. DEFINITIONS OF HEALTH EFFECTS ASSOCIATED WITH WATER-MEGS

EXPOSURE DURATION		HEALTH EFFECT	HEALTH EFFECTS AND PERFORMANCE DEGRADATION *
SHORT-TERM	5 days 5 or 15 L/day	MINIMAL TO NONSIGNIFICANT	The drinking water concentration for a continuous daily consumption of either 5 L/day or 15 L/day for up to 5 days that should not impair performance and is considered protective against significant non-cancer effects. Increasing concentration and/or duration could result in performance degradation, need for medical intervention, or increase the potential for delayed/permanent disease (e.g., kidney disease or cancer).
	14 days 5 or 15 L/day	MINIMAL TO NONSIGNIFICANT	The drinking water concentration for a continuous daily consumption of either 5 L/day or 15 L/day for up 14 days that should not impair performance and is considered protective against significant non-cancer effects. Increasing concentration and/or duration could result in performance degradation, need for medical intervention, or increase the potential for delayed/permanent disease (e.g., kidney disease or cancer).
LONG-TERM	1 year 5 or 15 L/day	NONSIGNIFICANT TO NONE	The drinking water concentration for a continuous daily consumption of either 5 L/day or 15 L/day for up to 1 year that should not impair performance and is considered protective against health effects including chronic disease and increased risk to cancer (i.e., cancer risk greater than 1×10^{-4}). Increasing concentration and/or duration could increase the potential for delayed/permanent disease (e.g., kidney disease or cancer).

* Sensitive individuals may be predisposed to toxic effects and, therefore, maybe more susceptible. If available scientific evidence regarding such subpopulations exists for a particular chemical, then this information is provided in the guideline tables.

2.1.3 Soil-MEGs: Daily Exposure through Contact, Ingestion, and Inhalation

Table 2-3 defines the Soil-MEGs and the meaning behind their exceedences. Soil-MEGs for 1-year (deployment-length) continuous exposures are presented in Appendix E. Soil-MEGs for short-term exposure scenarios were not developed for the following reasons. Typically, unless obvious odors, dead or discolored vegetation, or free chemical product is observed, soil contamination is not anticipated to be an immediate or severe hazard. If such conditions are observed, such areas that may contain contaminated soils are usually relatively easy to avoid.

Soil-MEG values are based on specific exposure assumptions that are described by daily rates of activity to include breathing rates, incidental soil ingestion rates, and dermal contact rates that are expected to be typical for military deployment operations. These soil guidelines are designed to indicate "thresholds" for no adverse health effects. As the parameters of the MEG are exceeded (e.g., chemical concentrations exceed soil MEGs, or exposure durations increase), it becomes more likely that greater portions of individuals in the exposed population will experience adverse health outcomes.

TABLE 2-3. DEFINITIONS OF HEALTH EFFECTS ASSOCIATED WITH SOIL-MEGS

EXPOSURE DURATION		HEALTH EFFECT	HEALTH EFFECTS AND PERFORMANCE DEGRADATION
LONG-TERM	1 year	NONSIGNIFICANT TO NONE	The soil concentration for continuous, daily exposure (from ingestion, dermal absorption, and inhalation) for up to 1 year (365 days) that should not impair performance and is considered protective against any health effects including chronic disease and increased risk to cancer (i.e., cancer risk greater than 1×10^{-4}). Increasing concentration and/or duration could increase the potential for delayed/permanent disease (e.g., kidney disease or cancer).

* Sensitive individuals may be predisposed to toxic effects and, therefore, maybe more susceptible. If available scientific evidence regarding such subpopulations exists for a particular chemical, then this information is provided in the guideline tables.

2.2 CHEMICAL HAZARDS WITH UNIQUE CONCERNS

2.2.1 Chemicals Warfare Agents (CWA)

The primary CWAs addressed by this TG include the nerve agents (GA, GB, GD, GF and VX) and the vesicants or blister agents (Sulfur Mustard (HD) and Lewisite). Currently, military risk management decisions regarding CWAs are somewhat unique in comparison to that of other TICs addressed by this TG. In part, this is because various Army, DoD and Joint Staff policy and doctrinal documents establish procedures and standards to address potential military exposure to CWA. Most of the existing operational Nuclear, Biological, and Chemical (NBC) policies and procedures focus on the wartime scenario. (See the back cover for a list of a few key NBC references.) Much of the responsibility is assigned to the Chemical Corps or designated NBC personnel. Much of the existing doctrine and equipment has focused on "presence-absence" identification as opposed to estimation of degree of risk. Medical responsibilities for NBC have historically been limited to casualty management with preventive medicine aspects focused on antidote development and administration. Today, with varying types of deployments and increased attention to health effects that may be more subtle and/or long lasting, the policies, doctrine, and even equipment (such as detection and monitoring devices) are undergoing evaluation and change. Requirements (HQDA Letter 1-01-1, 2001) to address mild or delayed health

effects in operational risk management – including scenarios involving potential residual or low-level CWA concentrations require more information than what has been previously incorporated into doctrine. Most scenarios involving CWA will still require Chemical/NBC personnel involvement. Follow-up and/or joint evaluation by medical/preventive medicine personnel is necessary to ensure that the potential for residual CWA contamination is appropriately considered and documented.

2.2.1.1 Air-MEGs

The Air-MEGs for CWAs (Table C-1) are based on the same technical and toxicological models that the other chemical Air-MEGs are based on with the exception of Lewisite, which has a limited toxicity database and therefore has guidelines derived largely from a conservative baseline detection limit. Therefore, the MEGs can be used to demonstrate relative potency or toxicity of the chemicals. The Air-MEGs for CWA are provided for 1-hour, 8-hour, and 24-hour exposure durations. Air-MEGs for the 14-day and 1-year exposure durations were not developed because CWAs are generally not persistent in the air for longer than 24 hours.

2.2.1.2 Water-MEGs

Drinking Water-MEGs are extracted directly from the doctrinal requirements of TB MED 577. These TG Water-MEGs are, therefore, "standards" which must not be exceeded. As with the air exposure pathway, extended exposure to small amounts of CWA in a drinking water source is not a plausible scenario (due to physical/chemical characteristics of the agent as well as the military requirements that would prohibit extended use of such a water source), therefore, only short-term CWA Water-MEGs are provided.

2.2.1.3 Soil-MEGs

Despite the general non-persistent nature of CWA in air and even water, binding to soil or other solid media can potentially extend the presence of CWA in a deployment setting. This is particularly true for the agents HD and VX. Cold temperatures and dry climates will tend to extend the persistence of these chemicals; on the other hand, rain and heat are natural mechanisms of degradation.

Decisions concerning reentry and post-decontamination scenarios (i.e., after air monitoring has cleared the immediate airborne hazard concern) may need to be validated through specific analysis of soil or other solid material. Soil-MEGs have been conservatively developed using the same model used to derive 1-year Soil-MEGs for other TICs in this TG.

2.2.2 Ambient Air Quality: Priority Pollutants and Particulates

The USEPA has identified seven "criteria pollutants" or "priority pollutants" as indicators of air quality and has established for each of them National Ambient Air Quality Standards (NAAQS) reflecting maximum concentrations above which adverse effects on human health may occur. The criteria pollutants are ozone (O_3), particulates [particulate matter (PM_{10}) and ($PM_{2.5}$)], carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and lead (Pb). The sources of these criteria pollutants include factories, power plants, incinerators, automobiles, construction activity, fires and windblown dusts.

As indicators of overall levels of airborne pollution, these pollutants are often of particular focus during deployment environmental surveillance and monitoring efforts. In recent environmental surveillance programs in Bosnia, Kosovo, and Kuwait, levels of these criteria pollutants have exceeded USEPA NAAQS. Ongoing investigations suggest that at high enough levels, these pollutants may be associated with increases in military sick call visits for upper respiratory illnesses. Though delayed or permanent health effects associated with yearlong exposures to these pollutants have yet to be confirmed, there are indications suggesting potential for development or exacerbation of illnesses such as asthma, chronic bronchitis, and theoretically, even cancer. Part of the difficulty in ascertaining the specific association of

a priority pollutant with a specific health effect is the confounding nature of pollution – in which multiple chemicals form unique mixtures in different environments. In general, exceeding guidelines for more than one priority pollutant can be assumed to be of greater health effect than if there was just a single pollutant, but the degree to which one pollutant may modify the effect of another is not well established.

In deployment assessment, sampling efforts during operations should monitor priority pollutants to identify potential adverse health effects to military personnel and to ascertain whether actions are warranted to minimize impacts. For example, pollutant levels might warrant minimizing strenuous outdoor activity at peak hours when pollutants are at their highest concentrations.

Specific short-term Air-MEGs are provided in TG 230 for carbon monoxide, sulfur dioxide, and nitrogen dioxide (see Appendix C, Table C-2). Long-term Air-MEGs have been established for pollutants included in the NAAQS that are consistent with the intent of other Air-MEGs derived for TG 230, which are protective of the military population for 24 hours per day, up to 1 full year (see Appendix C, Table C-3). Additional information and guidance specific to these criteria pollutants is presented in Appendix C, Table C-4.

2.3 POPULATION ASSUMPTIONS

The MEGs are based on the assumption that deployed military populations consist of relatively healthy and fit male and non-pregnant female adults. Deployed military personnel are assumed to be 18 to 55 years of age, with an average weight of approximately 70 kilograms (kg) (i.e., approximately 154 pounds). While a common assumption is that such individuals will have no predisposing physical or mental factors that could exacerbate exposure to environmental chemicals, such an assumption does not appear to be entirely supported through scientific evidence. While there are basic health and fitness requirements that must be met and maintained by military personnel, an assessment of the factors that can lead to chemical specific susceptibilities suggests that many of the primary factors exist for the deployed military population (which includes active duty, reserve, and National guard personnel) (See Section 1.4.4 and Appendix F of the RD 230 for additional discussion). Predisposing factors such as age (>40 years), illness (e.g., asthma), physical and emotional stressors, life-style choices (e.g., smoking or alcohol use), or unique genetic traits may alter susceptibility to a toxicant. These factors are common to both the general population and the deployed military population as well. So, while the MEGs are not specifically designed to address or protect individuals with hypersensitive or critical health conditions, some sensitive sub-populations (identifiable to include genetic subgroups, asthmatics, pregnant females) were factored into these guidelines.

Where intelligence estimates for an area of operation (AO) indicated hazards to known sensitive subpopulations, medical planners may consider establishing medical qualifications for deploying forces to prevent these subpopulations from deploying to the AO.

2.4 DIFFERENT MEGs REFLECT DIFFERENT EFFECTS

2.4.1 Meaning of MEG Exceedences and Predicted Incidence of Symptoms

To the extent possible, MEG values were developed in a manner to attempt to consistently represent designated "thresholds" of differing toxicological severity. However, since the quantity and quality of scientific data upon which the guidelines are based varies substantially amongst the chemicals, the accuracy with which the guidelines represent severity "thresholds" varies. In cases where data for a chemical was extremely limited, a margin of safety has been built into the derived guideline value. In some cases, exposures greater than the MEG can induce immediate adverse health effects that may impact upon the ability of personnel to accomplish their mission. In other cases, exposures greater than the MEG

simply indicate that there is an increased likelihood that a health problem could arise either during or after the deployment is completed. The degree and duration of health effects experienced will depend on: (1) the sensitivity and characteristics of the individual exposed; (2) the duration and frequency of exposures; (3) the concentration of the substance; (4) the rate at which the individual takes in the substance (such as breathing rate or water consumption rate); and (5) the levels of other substances present and their interaction.

In general, environmental concentrations equal to, or slightly greater than, the specified MEG, are expected to result in the specified type and degree of health effect in none to a small portion of individuals in the exposed military population. In some cases, however, the MEG represents a purely "protective" level where health effects should not be observed at all.

Though the MEGs are based on generally conservative interpretations of toxicological data, there are variations among the chemicals in the degree of conservatism. In addition, these MEGs are designed for assessing a single exposure scenario, and do not consider the impacts of multiple deployments with similar or variable chemicals exposures or the inevitable exposures that occur pre- and post-deployment during CONUS-based activities and/or personal time (e.g., related to hobbies or home activities).

2.4.2 Acute and Systemic, Non-Cancer Health Effects

For non-carcinogens, it is assumed that there is a threshold dose, which defines the minimal amount of a chemical necessary to cause a specific adverse health effect or group of effects. Below the threshold dose, a chemical compound is not expected to cause any biologically adverse change. The MEG values for non-carcinogens represent the best estimate of what the average human threshold dose would be under the specific exposure conditions described. Above these concentrations, it is possible that a variety of adverse symptoms of exposure may occur.

The types of health effects and toxicological endpoints associated with exceeding a particular chemical guideline are described in the MEG tables in Appendices C, D, and E. Because toxicological data are often limited, some potential health effects might not be identified. Similarly, there are uncertainties with ascertaining whether any, some, or all of the effects may actually occur. Due to human variability, it is also very difficult to quantify the percentage of exposed individuals that may be impacted. Therefore, trained personnel should interpret with caution any exceedences of a specific MEG. Understanding the *types* of effects and ascertaining whether short-term guidelines are exceeded is very important in determining the severity of the hazard. Also, noting the types of organs/systems that a chemical may effect is particularly important when there are multiple chemicals present and when some have the same types of effects. Tables 2-4-1 and 2-4-2 present the target organ and target systems upon which chemicals may have adverse impact. These groups are also notated along with each guideline in the MEG tables.

TABLE 2-4-1. TARGET ORGANS

TARGET ORGANS
Eyes
Skin
Blood
Bladder
Brain
Heart
Pancreas
Adrenal Glands
Lungs
Liver
Kidneys
Spleen
Thyroid
Bone
Fetus

TABLE 2-4-2. TARGET SYSTEMS

TARGET SYSTEMS
CNS – Central Nervous System
PNS – Peripheral Nervous System
GI tract – Gastrointestinal Tract
RS – Respiratory System
LRS – Lower Respiratory System
URS – Upper Respiratory System
CVS – Cardiovascular System
ChE Inh – Cholinesterase Inhibitor
UT – Urogenital Tract
CRC – Circulatory System
IMM – Immune System
REPR – Reproductive System
HEM – Hemopoietic System
ENDO – Endocrine System
LYMP – Lymphatic System

2.4.3 Cancer

Chemicals that are identified as cancer-causing (i.e., carcinogenic) can also cause local and/or other systemic health conditions. In such cases, both health effects were addressed for the selection of most MEGs. With the exception of severe effect 1-hour Air-MEGs, the majority of the MEGs are protective against local, systemic, and as well as significant excess cancer risk. The significance of cancer risk is unique from other toxic effects in that it is a "non-threshold" effect and therefore exposure at any level may be considered to increase the risk of cancer development. To address this in setting chemical exposure levels, Federal organizations such as the USEPA and Occupational Safety and Health Administration (OSHA) have established "acceptable" excess cancer risk levels. For purposes of TG 230, MEGs represent levels that are protective of excess cancer risks greater than 1×10^{-4}. A cancer risk of 1×10^{-4} means that 1 out of 10,000 equally exposed individuals would be expected to develop cancer as a result of the evaluated exposure. This is within the range of acceptable risk noted by other federal agencies and has previously been indicated an acceptable risk level for DoD (NRC, 1986b). Further discussion is provided in the RD 230, Section 3.1.5.

Uncertainty must be considered when characterizing the risk contributed by a chemical carcinogen. This includes consideration of the certainty with which the scientific community believes it to be a human carcinogen. Weight-of-Evidence (WOE) classifications (Table 2-5) are provided to characterize the degree of certainty with which the USEPA considers the chemical to, in fact, be a human carcinogen. These classifications should be incorporated into the overall risk characterization and confidence estimation process (for example, a chemical that is considered a "C" carcinogen may be considered to pose less risk than one classified as an "A").

TABLE 2-5. CHEMICAL CARCINOGENICITY CLASSIFICATION CODES *

CLASSIFICATION	DESCRIPTION
Class A: Human carcinogen	Sufficient evidence in epidemiological studies to support causal association between exposure and cancer.
Class B: Probable human carcinogen	Limited evidence in epidemiological studies (Group B1) and/or sufficient evidence from animal studies (Group B2).
Class C: Possible human carcinogen	Limited evidence from animal studies and inadequate or no data in humans.
Class D: Not classifiable	Inadequate or no human and animal evidence of carcinogenicity.
Class E: No evidence of carcinogenicity for humans	No evidence of carcinogenicity in at least two adequate animal tests in different species or in adequate epidemiological and animal studies.

* While technically only group "E" chemicals may be firmly stated to be "non-carcinogens", chemicals that fall into a "D" category are also not assessed as carcinogens. Chemicals that are "C" carcinogens may be assessed with caution as carcinogens with an understanding of the conservatism and uncertainty involved with the associated database. In general, focus should be on carcinogens with classifications of A, B1, and B2.

SECTION 3

RISK ASSESSMENT APPLICATIONS

> Risk decisions are a commanders business. Such decisions are normally based on the next higher commands guidance on how much risk he is willing to accept and delegate for the mission.
>
> —FM 100-14, Risk Management

> Risk management is an effective process for preserving resources. It is not an event. It is both an art and a science.
>
> —FM 100-14, Risk Management

> A philosophy of dealing with any harm [to deployed personnel] should be clearly stated, widely disseminated, ethically based, practical, and comprehensive. This will allow commanders to make informed decisions and be flexible rather than having to deal with prescribed limits when they may be inappropriate or impractical . . .
>
> —Institute of Medicine (1999)

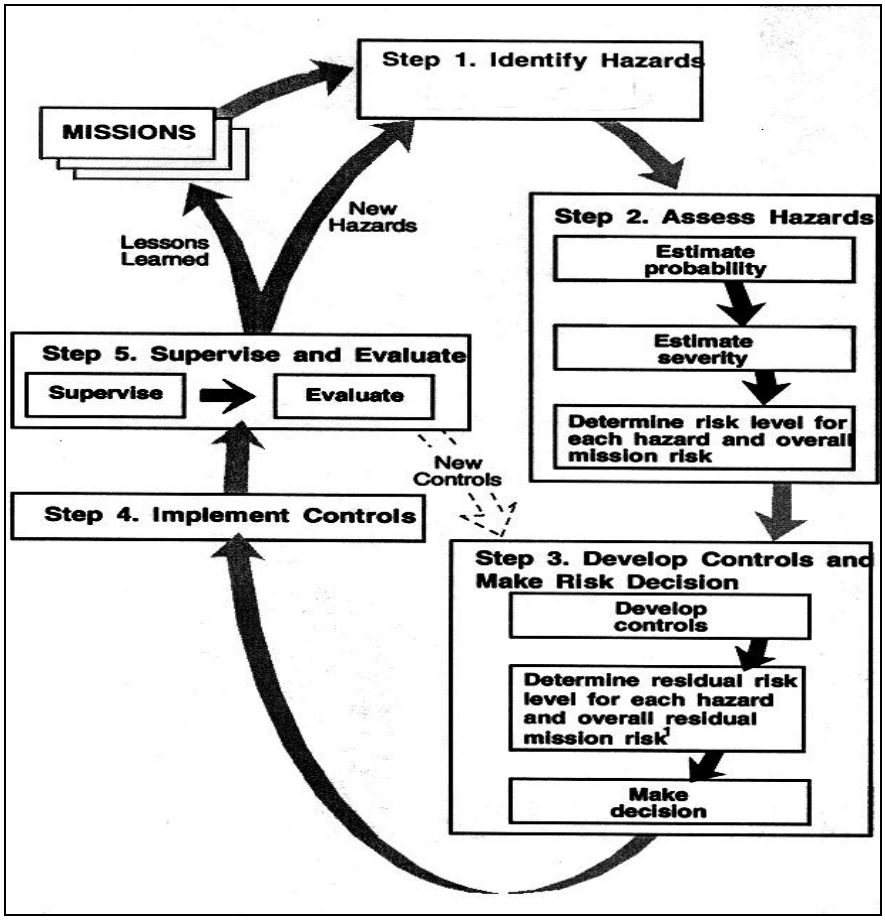
TG 230 MEGs are best utilized in risk assessments supporting ORM decisions. TG 230 should be used in concert with TG 248, which provides guidance for assessing and managing OEH hazards within the military ORM framework. TG 248 also identifies those preventive medicine tasks that support OEH surveillance and the responsibilities for various assets within the preventive medicine hierarchy.

3.1 OPERATIONAL RISK MANAGEMENT

Army risk management doctrine, as detailed in FM 100-14, provides commanders with methods to evaluate and manage the risks posed by operational hazards to the force. In addition, FM 3-100.4, *Environmental Considerations in Military Operations*, provides doctrine for managing environmental risks. These two documents provide an initial framework for characterizing environmental hazards. This framework is an iterative process that is integrated into operational planning and decision-making at all levels. Leaders manage risk by evaluating hazards and implementing ORM options during course of action (COA) development (see Figure 3-1).

The ORM approach is a process for identifying, assessing, and controlling risks as well as evaluating the effectiveness of risk control measures. This TG, in context of TG 248, addresses OEH chemical hazards that may pose health threats to individual troops. These can ultimately be expressed as medical threats to the force and the mission. The goal of TG 230 MEGs is to provide a useful tool to assist field commanders and their staff in the production of risk assessments and making informed ORM decisions that consider OEH hazards. Preventive medicine personnel should participate in the ORM process by identifying OEH hazards, assessing the threat associated with hazards, characterizing the risks in context of the proposed COA, effectively transmitting the risk assessments, and recommending appropriate control measure options to the commander. Preventive medicine personnel should also assist in implementing commander-selected control measures (e.g., provide health risk communication), evaluate effectiveness of control measures in controlling health threats, and document the ORM assessment to aid in subsequent re-assessments and in providing lessons learned for future deployments.

FIGURE 3–1. OPERATIONAL RISK MANAGEMENT PROCESS



3.2 HEALTH THREAT AND MEDICAL THREAT CONCEPTS

Health threats and medical threats represent different levels of importance to military operations. A health threat can cause negative health effects to a soldier. A medical threat is more severe and has the ability to render a field unit combat or mission ineffective, and lead to casualties reporting for medical diagnosis and treatment. Preventive medicine personnel must document assessments for both health threats and medical threats. For medical threats, preventive medicine must notify commanders of the mission impact, and most notify troop clinics and other medical treatment units of potential casualties. These terms are defined in FM 4-02.17, *Preventive Medicine Services*, as follows:

> ✍✍Health threat refers to an individual soldier's health. The term can include hereditary conditions that manifest themselves in adulthood, individual exposure to an industrial chemical or toxin where others are not exposed, or [conditions that can result in] other injuries and traumas that affect an individual's health but may not affect the health of the unit. On the other hand, a unit that experiences 40 to 50 percent of its personnel exhibiting a debilitating condition (e.g., salmonella poisoning), the unit can no longer complete its mission.

✍✍Medical threats are a sub-set of health threats that have the potential to degrade a unit's combat (or mission) effectiveness. Medical threat is defined as "a collective term used to designate all potential or continuing enemy actions and environmental situations that could adversely affect the combat effectiveness of friendly forces, to include wounds, injuries, or sickness incurred while engaged in a joint operation" (see Joint Publication 4-02, *Doctrine for Health Services Support in Joint Operations*). In Army and multi-service publications, the term is defined as a composite of all ongoing potential enemy actions and environmental conditions and disease and non-battle injuries (DNBI) that may degrade a unit's combat effectiveness. Commanders and unit leaders are responsible for protecting and preserving Army personnel and equipment against injury, damage, or loss that may result from food-, water-, and arthropod borne diseases, as well as environmental injuries (e.g., heat and cold injuries) and occupational hazards.

The TG 248 ORM framework intends to consider both kinds of threats; however, medical threats are more important to possible mission failure than non-medical health threats. On the other hand, controlling unit health threats *in toto* would be the focus of FHP and maintaining unit readiness.

3.3 MEGs AND OPERATIONAL RISK ASSESSMENTS

To reemphasize, this TG does not establish "standards" that must be strictly adhered to, nor do their use represent a comprehensive, health risk assessment. MEGs are one tool to be used by trained preventive medicine personnel who may be required to inform their commanders of potential adverse health effects caused by chemical environmental contaminants and to identify potential impacts on the mission. This TG provides the evaluation criteria and methods to facilitate appropriately cautious, yet defensible, logical and consistent decision-making. The decision to minimize the potential health risks by avoiding exposure to particular adverse environmental conditions or providing protective equipment will always need to be balanced against the requirements of the mission itself. These decisions are ultimately those of the commander. It is the health service or preventive medicine officer's role to ensure that the commander has the essential information to make the most appropriate decision.

The process of assessing and characterizing health risks from chemical exposures inherently involves significant data limitations, uncertainty, variability, and professional judgment. Therefore, this TG cannot provide absolute answers. But the consistent application of the framework described along with the technical information and concentration levels, as well as suggested interpretations, can lead to appropriate and defendable decision making. The process described below (and more importantly the hypothetical case studies in Appendix F) provide the user with the baseline information from which they can build personal experience.

This TG is an effort to take technically complex information regarding potential health risks from a variety of hazards and translate such information for use in the traditional, standardized military ORM paradigm. If appropriately used, this TG and the ORM process will ensure that risks of greater significance are given top priority. To do this, it is necessary that all hazards be initially identified. Once identified, the severity and probability of the hazards is assessed to determine overall degree of risk. Then all risks are evaluated, compared, and decisions made which often result in decisions to mitigate/prevent some risks while accepting others.

This section will assist medical/preventive medicine personnel in putting chemical hazards in proper perspective and relay appropriate information through command levels as well as to fellow personnel. The information in this TG will help minimize errors in judgment that could be made either by over-estimating chemical hazards as a result of perceptions or media hype, or, in contrast, ignoring such

hazards because they traditionally have not been a military concern. Proper assessment of chemical hazards and potential control actions can prevent or reduce DNBI to ensure long-term health of the force. Or, when other more significant risks are present, the 'acceptance' of risk associated with a chemical exposure can be clearly demonstrated with the ORM process described herein.

Each risk assessment should be prepared in context and support of a larger risk management effort. The key risk assessment steps within the larger FM 100-14 risk management process, as described in TG 248 (*Guide for Deployed Military Personnel on Health Hazard Risk Management*) were used as guidance and are outlined below:

1. *HAZARD IDENTIFICATION*
   - *1.1. METT-TC: chemicals, media, and locations*
   - *1.2. Preliminary threat analysis*
2. *HAZARD ASSESSMENT*
   - *2.1. Hazard severity evaluation*
   - *2.2. Hazard probability evaluation*
   - *2.3. Risk characterization*
     - *2.3.1. Estimate risk*
     - *2.3.2. Establish confidence level*
     - *2.3.3. Determine threat category*
3. *DEVELOP AND COMPARE CONTROLS FOR COA DEVELOPMENT*
   - *3.1. Develop hazard controls*
   - *3.2. Determine residual risks*
   - *3.3. Recommend actions to increase confidence in risk estimates*
4. *IMPLEMENT CONTROLS*
5. *SUPERVISE AND EVALUATE*

The following subsections summarize the requirements necessary to complete risk assessment Steps 1, 2, and 3. TG 248 and FM 100-14 provide procedures for health service activities in implementing ORM Step 4 (e.g., risk communication as part of implementing controls through), ORM Step 5 (e.g., assessing effectiveness of controls), and documentation of ORM activities.

3.3.1 *ORM STEP 1 — HAZARD IDENTIFICATION*

Step 1.1 METT-TC: Chemicals, Media, and Locations

An OEH chemical hazard is any chemical or chemical mixture that can cause injury, illness, disease, adverse health conditions, or death for personnel (health threats). Such conditions may also affect the health status of the Command (medical threats). During the intelligence preparation of the battlefield (IPB) in the application of METT-TC factors[1], the identification of an OEH chemical hazard involves the presumption or detection of an exposure to the chemical. Chemical hazards can be associated with different media (e.g., air, water, soil, food) and exposure routes. Exposures can occur via inhalation of airborne chemicals as mists, vapors, gases or solids (fumes or dusts). They can also occur via ingestion of drinking water or the inadvertent ingestion of soil. Dermal contact with some chemicals can also be a hazard under some conditions. Identification of these hazards can include collection of information through intelligence channels, field sampling, exposure or accident modeling, or a combination of all methods. TG 248 and TG 251 (*Draft Environmental Health Field Sampling Guide for Deployments*)

[1] METT-TC: Mission, Enemy, Terrain and Weather, Troops, Time, Civilian

provide additional guidance on gathering, organizing, and validating the following types of chemical hazard information:

?? Using field data to estimate exposure: The user of this TG should become familiar with the basis, assumptions, and limitations associated with the MEG values presented in the tables and should also be able to critically assess how representative field-collected sampling data is for characterizing actual personnel exposures. In many cases, a limited number of samples will be obtained, and it will require professional judgment of trained preventive medicine staff to determine what exposures are truly anticipated throughout the deployment. The ORM framework requires not only an assessment of the severity of a hazard (i.e., exposure concentrations below the guideline indicate a negligible hazard but higher concentrations could signify a minimal to moderate hazard), but it also requires an assessment of the probability of the hazard (i.e., exposure above the designated guideline). Though real-world scenarios cannot entirely separate issues of probability and severity, this TG focuses on aspects of assessing severity.

?? Understanding the population of concern: To use these guidelines, field data should also include information about the population of concern (who/what percent of the overall unit is at risk of exposure and what operations will they be involved with that could affect how they are exposed). The user needs to evaluate the anticipated exposure durations at given concentrations, as this will be important in determining the overall severity of the hazard.

?? Pesticide use and surveillance: Some unique activities involve intentionally placing chemicals in the environment. Pesticide contamination due to pest control operations may lead to chemical residues in the environment. Of particular concern in this regard is pesticide contamination caused by host nation activities in an area subsequently occupied by U.S. Forces supporting a contingency operation. It is critical that initial levels of pesticide contamination in such areas be recorded prior to initiation of pest control operations to facilitate distinguishing between prior contamination and any accidental contamination caused by pest control operations in support of U.S. activities. It is important to note that pesticide contamination in a given area does not necessarily obviate the need for additional chemical pest control in that area. Pest and disease vector populations, though present in the vicinity of a contaminated site, often exist in microhabitats that are completely isolated from the contaminated zones, and so are not exposed to the contaminant. Thus, targeted pest control operations may still be warranted in such scenarios.

Step 1.2 Preliminary Threat Analysis

The purpose of this sub-step is to prioritize identified OEH hazards so that the risk assessment focuses on the most important threats first. In order to focus additional risk characterization efforts and possible data collection, the risk assessor must determine which of the identified chemical hazards pose HEALTH THREATS to personnel under site-specific conditions or are MEDICAL THREATS to the mission. The three types of threat classifications for OEH hazards are presented below and in Figure 3-2.

✍✍NO CHEMICAL HEALTH THREAT can be assigned to a chemical hazard only when there is no evidence to indicate its presence in the environment of concern or there is enough data to know that the concentration and extent of its presence would not pose a credible health threat.

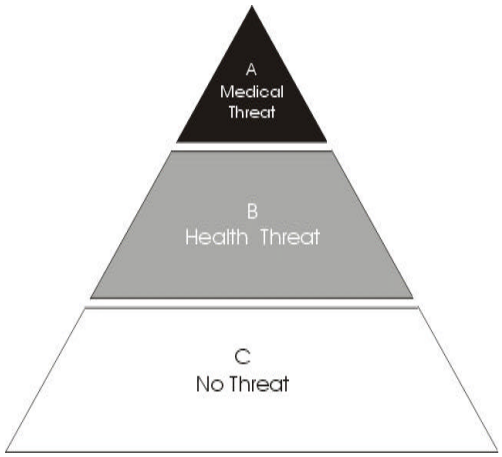
✍✍CHEMICAL HEALTH THREATS are all identified chemicals within the AO that, under plausible circumstances, could result in adverse health effects to certain individuals. For example, a chemical hazard may result in temporary mild headaches or nausea to certain sensitized individuals or may induce health effects with delayed onset (e.g., chronic diseases like cancer or impaired liver and kidney function) but have no immediate, mission impacting effect.

Commanders may still choose to incorporate such hazards into his or her risk management process, regardless of immediate impacts to the mission (e.g., during operations other than war).

✍✍CHEMICAL MEDICAL THREATS Depending on the mission, such hazards include chemical exposures that might result in effects such as severe eye irritation/blurred, vision, severe dizziness/confusion, seizures, death, or would otherwise result in sick calls or medical interventions.

FIGURE 3–2

Hierarchy of OEH Hazards to the Military



Determining OEH hazard categories:

In general, if concentrations of a detected chemical consistently fall below the 1-year MEG values, then one may assume that the identified OEH hazard does not pose a health threat. Therefore, the use of the 1-yr MEG values to "screen" identified chemicals/hazards of concern is encouraged before the risk assessment proceeds into Step 2 (Hazard Assessment). If exposures will not last longer than 14 days, then use of the 14-day MEGs is acceptable to "screen" for the occurrence of a health threat before proceeding. In all cases, professional judgment in selecting the most appropriate guidelines for comparison is required. In many cases, the operational risk assessment can end at this stage if it can be demonstrated that the exposure concentrations do not pose a health threat to personnel. There are many uncertainties that must be considered in such determinations. For example, there will be a variety of situations where actual exposures are not consistent with those in the guidelines.

?? Estimating the exposure concentration to compare to the MEG. Environmental monitoring may indicate fluctuations in actual concentrations over time. The MEGs should be compared with the most representative exposure concentration associated with the actual scenario of concern. While averaging exposure levels spatially and temporally is one appropriate way to look at data, it should be noted that peaks of short duration may have health effects—so the user should assess data against all guidelines and durations at this stage in the process. If any MEG is exceeded, then in most cases that exposure scenario should proceed to Step 2 of the process. The hypothetical case studies in Appendix F provide some guidance as to how this can be accomplished.

?? Multiple chemical exposures. Each MEG has been established to be protective against exposure to a single chemical. The complex issue of multi-chemical exposures and effects of chemical interactions is beyond the scope of the TG, but such effects should be considered in the overall evaluation of environmental exposures. Since certain contaminants may have similar adverse effects on the human body, it is necessary to consider the total sum of all similar effects. Unfortunately, little is known regarding the specific interactions of multiple contaminants. A specific quantitative technique for assessing multiple contaminants in a deployment setting is not feasible at this time. Instead, users are encouraged to note the possibility of added hazards, particularly where chemicals have similar effects or known interactions are listed. This information should be used in conjunction with professional judgment. (Interactions are notated in the "Notes" column of the MEG tables. In particular, note the target organ column.) If two or more chemicals have the same target organs or systems (see Section 2.4.2) , then it may be considered that their effects can be additive or synergistic. For some specific chemicals, such as

total petroleum hydrocarbon (TPH) compounds or carcinogens (particularly those with an A or B WOE classification) it is generally assumed that effects of the different chemicals when combined are at least additive.

?? Multiple exposure pathways. In addition to the potential additive effects of multiple contaminants, military personnel may be exposed to the same contaminants from multiple sources (e.g., air, water, and soil). The effects of exposure to the same or similar chemicals through different media should be considered additive. Users are encouraged to note that exposure (through multi-media) may increase overall exposure. This information can be used when ranking OEH hazards.

?? Chemical hazards without MEG values. Where this TG lacks a MEG for an identified chemical, we recommend the health staff follow these steps: (1) contact USACHPPM for assistance in establishing a MEG; (2) research the chemical (e.g., literature or internet resources) and establish a surrogate MEG; (3) establish a risk estimate based on similar chemicals in this TG and document the uncertainty (i.e., reduced confidence) in the risk characterization (Sub-step 2.3). Additional information is provide in Section 1.4.4.

3.3.2 *STEP 2 — HAZARD ASSESSMENT*

OEH hazards that proceed into this step of the operational risk assessment will usually be present in air, water, or soil at concentrations greater than 1-yr or 14-day MEG values depending on the duration of the exposure.

Step 2.1 Hazard Severity Evaluation

An OEH chemical hazard severity category represents "the potency of the chemical to cause injury, illness, disease, adverse health conditions, or death integrated with the significance of the health consequences for personnel relative to the ability of the field unit to complete the mission or maintain readiness" (TG 248, 2001).

When field concentrations exceed 1-year MEGs, users must attempt to estimate the severity of the health threat. For air and drinking water, users should first determine whether any short-term standards are also exceeded. If the exposure duration is 1 year and a 14-day, 8-hour, or 1-hour MEG is exceeded, then some significant health and/or mission impacts may be anticipated. For many chemicals with long-term guidelines, however, there are no parallel short-term guidelines. In such cases, the user may have to rely on professional judgment as to the severity of the hazards. In practice, any "conclusion" and estimation of the severity of health threat must be made with an understanding of the limitations of currently available data that forms the basis of the MEG and of the risk-assessment process in general. Appendix F provides examples of how hazard severity can be determined.

A chemical's hazard severity is a function of the consequence of exposure for any given individual in the unit and the predicted distribution of that impact within the field unit. Unfortunately there is often limited human toxicological or epidemiological data for most chemicals, and limited information regarding human response variability and genetic susceptibilities to most chemicals, making it difficult to know specifically what health effects to anticipate or, even more difficult, to ascertain the percentages of an exposed population that will exhibit certain effects. However, to the extent possible, the following considerations will need to be factored into assigning a hazard severity category to a chemical hazard.

?? Proportion of the field unit that is likely to exhibit effects relative to the specific exposure guidelines.

?? Nature of the health effect(s) associated with exposures at or above the guideline level.

?? Confidence in the available data, given the sources of uncertainty and variability.

Based on these considerations, one of the following categories from FM 100-14 should be assigned to an identified chemical hazard:

CATASTROPHIC — Loss of ability to accomplish the mission or mission failure.
CRITICAL — Significantly (severely) degraded mission capability or unit readiness.
MARGINAL — Degraded mission capability or unit readiness.
NEGLIGIBLE — Little or no adverse impact on mission capability.

The Hazard Severity Ranking Chart presented in Table 3-1 is a recommended approach:

TABLE 3-1. CHEMICAL HAZARD SEVERITY RANKING CHART FOR MILITARY DEPLOYMENTS

MAGNITUDE OF CHEMICAL CONCENTRATION							
	WATER	< MEG	= MEG that is not based on TB MED 577 (See Water Note)		= MEG that is based on TB MED 577 (See Water Note)	See Water Note	See Water Note
	SOIL	< MEG	= MEG (See Soil Note)		See Soil Note	See Soil Note	See Soil Note
	AIR	< 1-yr MEG or < 14-day MEG	= 1-yr MEG or = 14-day MEG but = 1 to 24-hr Min-MEGs	≥ 1-yr MEG or ≥14-day MEG but > 1 to 24-hr Min-MEGs	> 1-hr Min-MEG but ≤ 1-hr Sig-MEG	>1-hr Sig-MEG but = 1-hr Sev-MEG	> 1 hr Sev-MEG
IN GENERAL, THE ASSOCIATED HEALTH OUTCOME ATTRIBUTIBLE TO EXPOSURE (Percentages are very uncertain and will vary by chemical and other confounding factors.)		No cases of illness or non-cancer disease and less than 1 cancer case in 10,000	0 – 10 % of personnel may develop illness or chronic disease	0 – 10 % of personnel may develop mild illness or temporary irritation	> 10 % of personnel may experience mild illness, irritation AND 0 – 10 % of personnel may develop more severe illness that begins to impair functional abilities.	10 – 25 % of personnel may experience severe illness or irritation and more noticeable degradation of performance capabilities AND Other personnel will, at least, suffer some mild effects	> 25 % of personnel may experience severe, incapacitating effects AND Fatalities will begin to occur just above the Sev Air-MEG with increasing number of fatalities as concentrations increase
ONSET OF SYMPTOMS		After the Mission		During the Mission			
HAZARD SEVERITY RANK		NONE	NEGLIGIBLE		MARGINAL	CRITICAL	CATASTROPHIC
HAZARD TYPE		NO HEALTH THREAT	HEALTH THREAT		MEDICAL THREAT		

WATER NOTE: Concentrations greater than the MEG *may* result in Hazard Severity from Marginal to Catastrophic if certain chemicals are present in high enough quantities and there is sufficient consumption. Additional information in the Notes column of the MEG Tables should be evaluated regarding effects of higher levels of exposure.

SOIL NOTE: Soil is unlikely to represent a hazard that would yield a Medical Threat. Additional information in the Notes column of the MEG Tables should be evaluated for data regarding higher levels of exposure.

Min-MEG: minimal effects level from Appendix C, Tables C-1 & C-2.
Sig-MEG: significant effects level from Appendix C, Tables C-1 & C-2.
Sev-MEG: severe effects level from Appendix C, Tables C-1 & C-2.
1-yr MEG: values from Table C-3.

Step 2.2 Hazard Probability Evaluation

An OEH chemical hazard probability category represents "the magnitude, frequency and duration of personnel exposure to the identified chemical(s) integrated with the expected incidence of exposure within the unit relative to associated guideline levels" (TG 248, 2001).

Determining the chemical hazard probability category will generally be a very subjective evaluation, where three primary considerations are used to determine the potential degree of exposure:

?? Comparability of the field unit's exposure profile (exposure factors, frequencies, and durations) to the standard exposure profile used in the derivation of the exposure guideline(s) of concern.

?? Proportion of the field unit that is likely to experience exposures relative to the specific exposure guidelines.

?? Confidence in the available data, given the sources of uncertainty and variability.

Based on these considerations, one of the following categories from FM 100-14 should be assigned to an identified chemical hazard to indicate the probability of personnel exposures to concentrations equal to or greater than the MEGs:

FREQUENT — Occurs very often, continuously experienced
LIKELY — Occurs several times
OCCASIONAL — Occurs sporadically
SELDOM — Remotely possible; could occur at some time
UNLIKELY — Can assume will not occur, but not impossible

The following Hazard Probability Ranking Chart (Table 3-2) is based on TG 248, and is a recommended approach than can be altered as the situation dictates.

TABLE 3-2. CHEMICAL HAZARD PROBABILITY RANKING CHART FOR MILITARY DEPLOYMENTS

PERCENT OF PERSONNEL THAT WILL EXPERIENCE EXPOSURES TO CONCENTRATIONS EQUAL TO OR GREATER THAN THE MEG*				
<10%	10< 25 %	25 <50 %	50 <75 %	>75 %
Unlikely	Seldom	Occasional	Likely	Frequent

*Determination of the percent of personnel exposed to a chemical or mixture specifically above a guideline level can be based on modeling, gridding, or generalized assumptions.

Step 2.3 Risk Characterization

Step 2.3.1 Estimate Risk

The risk level is estimated using the probability and severity information from the previous sections. The primary objective is to apply the FM 100-14 Risk Assessment Matrix (Table 3-3) in a way that is consistent with operational guidance, so that OEH risks can be put in the same context as other operational risks.

ORM risk levels defined in FM 100-14 (Table 3-3) are presented with unit status suggestions from FM 101-5-1 in Table 3-4 to create an OEH risk characterization paradigm that is consistent with current operational doctrine. The concept of unit strength status (e.g., "below 50% strength") refers to the overall loss of resources that would otherwise be directed towards the planned mission tasks. For every casualty (i.e., significant through severe effects that result in functional loss) one can expect the loss of additional personnel due to medical and related support for that casualty.

TABLE 3-3. RISK ASSESSMENT MATRIX (FM 100-14)

HAZARD SEVERITY		HAZARD PROBABILITY				
		Frequent (A)	Likely (B)	Occasional (C)	Seldom (D)	Unlikely (E)
		?	**?**	**?**	**?**	**?**
Catastrophic (I)	**?**	Extremely High	Extremely High	High	High	Moderate
Critical (II)	**?**	Extremely High	High	High	Moderate	Low
Marginal (III)	**?**	High	Moderate	Moderate	Low	Low
Negligible (IV)	**?**	Moderate	Low	Low	Low	Low
		RISK ESTIMATE				

Some past interpretations of the FM 101-5-1 unit status definitions have placed the lethal concentration for half of the population (LC_{50}) as the point at which a Catastrophic hazard - Extremely High risk would begin. This interpretation ignores two facts: (1) with a 50 % mortality rate due to chemical exposure, there would also be a large percentage of personnel with significant health effects other than death that would likely cause incapacitation and (2) medical support would be required to tend to those who were injured. As a result, at an LC_{50} concentration, unit strength would be much less than 50 percent resulting in possible complete combat ineffectiveness. Therefore, the MEGs presented in this TG are based on thresholds for the various types of effects noted (e.g., the 1-hour severe Air-MEG refers to approximately a 1% lethality concentration (LC_{01}) for an exposed population). Some may view this as a conservative interpretation of the FM 101-5 unit status codes and FM 100-14 risk definitions, but this does address a more comprehensive assessment of the true, overall impact on unit resources and combat effectiveness.

TABLE 3-4. RISK LEVEL DEFINITIONS

Risk Level	Defined Consequence (FM 100-14)	Unit Status (FM 101-5-1)
Extremely High	Expected loss of ability to accomplish the mission.	Black (Unit Requires Reconstitution). Unit below 50% strength.
High	Expected significant degradation of mission capabilities in terms of the required mission standard, inability to accomplish all parts of the mission, or inability to complete the mission to standard if hazards occur during the mission.	Red (Combat Ineffective). Unit at 50 – 69 % strength.
Moderate	Expected degraded mission capabilities in terms of the required mission standard will have a reduced mission capability if hazards occur during mission.	Amber (Mission Capable, with minor deficiencies). Unit at 70 - 84% strength.
Low	Expected losses have little or no impact on accomplishing the mission.	Green (Mission Capable). Unit at 85% strength or better.
The unit rates provided under Unit Status are to be determined by the commander. Charts similar to the example OEH Hazard Probability and Severity Ranking Charts presented above should be aligned with the acceptable risk levels provided by the commander.		

Step 2.2.2 Determine Confidence in Risk Estimate

A confidence level should be assigned to each risk estimate. The degree of confidence will be particularly important when determining possible courses of action. Confidence levels should be simple categories that can be rationally explained (e.g., high, medium, low). The confidence level assigned to a risk estimate should integrate uncertainty associated with each of the elements of the risk assessment. Key areas of uncertainty that should be considered include:

- ?? Sampling or field data quality
- ?? Actual exposures of field personnel
- ?? Field unit attributes (e.g., demographics, activity patterns)
- ?? Comparability of standard guideline assumptions (e.g., exposure duration, exposure frequency, and route of exposure) to expected field exposure patterns
- ?? Expected symptoms of exposure (i.e., hazard severity), including consideration of exposure to multiple hazards
- ?? Other uncertain, or missing, information relevant to the process
- ?? Whether the predicted health outcome is plausible, given weight of evidence or real-world experiences

Table 3-5 provides example criteria for determining a risk estimate confidence level. The final determination of confidence should be based on well-reasoned judgment of the staff officer conducting the risk assessment. As stated previously, it is important for the user to realize that - due to limitations in toxicity data, the nature of chemical exposures, and human variability - OEH chemical risk assessments should almost never be ranked with high confidence. For the most part, the MEGs are conservatively designed so that confidence in estimated *Low Risks* will tend to be greater than those estimated to be *High Risk*.

TABLE 3-5. EXAMPLE CRITERIA FOR ASSIGNING CONFIDENCE LEVELS

Confidence Level	Criteria
High	Sampling data quality is good. Field activity patterns are well known. True exposures are reasonably approximated. Knowledge of the symptoms of hazard exposure relative to guideline is well known. No important missing information. The predicted health outcome is plausible or already demonstrated.
Medium	Field data quality is good. Field exposures are likely to be overestimates of true exposures due to incomplete data coverage relative to actual exposure durations. Detailed information is lacking regarding true personnel activity patterns in the field. Symptoms are well known for each individual hazard, but some scientific evidence suggests that the combined effects of all hazards may exacerbate symptoms. Predicted health outcome is plausible.
Low	Important data gaps and/or inconsistencies exist. Exposure conditions are not well defined. Field personnel activity patterns are basically unknown. Predicted health outcome is not plausible because it is not consistent with real-world events/experience.

Step 2.3.3 Determine Threat Category

During Step 1 (Hazard Identification), a preliminary threat analysis was conducted for each of the identified chemical hazards. During Step 1 the goal was to determine which of the hazards have a credible potential to become HEALTH THREATS or MEDICAL THREATS in order to focus additional data collection and risk characterization efforts. At this point in the process, the preliminary analysis should be re-evaluated based on the more complete assessment of the nature of the hazards and the conditions of exposure. The placement of the hazards into health threat categories (no threat, health threat, and medical threat) is the last step in risk characterization. It is important for the command to understand that some hazards pose a greater potential to operations than others, even though the risk estimates may be similar. The command will have a preference to control medical threats over health threats. This sub-step is designed to provide the command with a useful ranking of the hazards faced by the unit and mission.

3.3.3 *Step 3 — Developing and Comparing Controls*

Risks are managed by either choosing the least risky COA and/or by incorporating control measures into one or more of the COAs that will address any identified environmental and occupational risks. Chemical hazard risk management strategies will fall into one of five general categories (Table 3-6).

TABLE 3-6. RISK MANAGEMENT STRATEGIES

RISK MANAGEMENT STRATEGIES	ATTRIBUTES
No Action	An implicit acceptance of the risk by the command.
Reduce Risk	Allowing exposures to occur but using control measures to reduce hazard severity and/or probability so as to reduce the true risk to a more acceptable level.
Avoid/Prevent Exposure	Use of engineering or administrative methods to prevent or completely avoid exposures of concern.
Interim Controls and Risk Re-assessment	Any combination of the above measures can be used as an interim action to address predicted risks that are of low confidence while obtaining additional data to increase the confidence in the risk estimate(s) before final decisions are made.
Health Surveillance	Use of medical and environmental surveillance systems to monitor ambient conditions (e.g., routine air monitoring) or personnel (e.g., bio-monitoring). This is not a means to directly control chemical hazards, but it can provide information to support or change a chosen risk management strategy.

Step 3.1 Develop Chemical Hazard Controls

Selection of possible control measures will be situation-specific and will involve a balancing of resources based on costs and benefits, consideration of time constraints, and appreciation of other real-world issues such as political sensitivities. To be effective each control developed must meet criteria for suitability, feasibility, and acceptability (FM 100-14). For a control to be suitable it must actually remove the hazard or mitigate the residual risk to an acceptable level. Feasible controls are those that the unit is capable of implementing. Acceptable controls are those that justify the costs of resources and time. Acceptability of controls is a command decision. Table 3-7 provides examples of control measures that can be used for dealing with chemical hazards.

TABLE 3-7. EXAMPLES OF CHEMICAL HAZARD CONTROL MEASURES

ADMINISTRATIVE	ENGINEERING	PERSONAL PROTECTIVE EQUIPMENT
Moving location of operations	Substitute use of less hazardous materials	MILITARY PROTECTIVE MASK (M-40,M-17)**
Managing deployment length/work schedules	Use of ventilation/increase dispersion	Commercial respiratory protection
Providing prophylactics/medical interventions that will reduce severity of effect	Isolate areas/build barriers or enclosures to prevent chemical release or human exposures	Eye protection
Enforcing personal hygiene standards	Use of filters (air or water purification systems)	Chemical protective Clothing
Active dust suppression measures		Normal battle dress uniforms (BDUs)/gloves

** NOTE: The military protective mask is only approved for against NBC-warfare agents; it may not offer adequate protections against other TICs.

Step 3.2 Estimate Residual Risks

Once suitable and feasible hazard control options are identified, the residual risk(s) associated with the implementation of the controls must be assessed. This process is a basic re-iteration of Steps 1 and 2 of the process. Possible control measures, or other risk management strategies, should be communicated to the command with the associated residual risk estimates.

Step 3.3 Recommend Actions to Increase Confidence in Risk Estimates

While in almost all cases there will be data gaps that can be improved with additional data, it is understood that there are logistical and time constraints that will require decisions to be made without the opportunity to increase confidence with more data. Because risk assessments are inherently uncertain, ways to reduce critical uncertainties should be explored if the risk assessment confidence levels are low to medium. This is particularly important if the generated risk estimates are high or extremely high, as control measures will require significant actions that dramatically impact the mission or involve notable resource expenditures, and there is reason to believe that specific types of data will be able to improve the confidence level. In these cases, additional data can either reduce the risk estimate or provide stronger justification of a need for drastic control measures.

3.3.4 *Steps 4 and 5 - Implementing Controls; Supervising And Evaluating*

Implementing the course of action selected during Step 3 requires a command decision, but to be successful will generally require continuous input and assessment by various staff elements who may at times need to recommend alternative decisions. Courses of action may include decisions to accept exposures or to avoid them by leaving an area, minimize them through use of protective measures, and/ or document them by performing routine monitoring. Each of these will have impacts to the mission, whether it is from use of limited resources (such as conducting regular monitoring) or impacts to morale and overall physical wellness. PM responsibilities should consider these impacts during Step 3, but must evaluate the situation once the action is initiated. Additional requirements, such as health risk communications briefings to personnel and/or command staff, may be identified through these continued evaluations. Some of the Hypothetical Case Scenario Examples in Appendix F demonstrate these final steps of the ORM process.

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APPENDIX A

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APPENDIX B

GLOSSARY OF TERMS AND ACRONYMS

Glossary of Terms (Acronyms begin on B-7)

Acidosis
Decrease of alkali in the blood, which may result in a decrease in the pH. Symptoms include very deep respirations, dehydration, drowsiness, stupor, or coma.

Anorexia
Loss of appetite.

Anoxia
Lack of oxygen.

Anuria
Complete urinary suppression or failure of kidney function.

Ataxia
Inability to coordinate muscles in movement.

Azotemia
An excess of urea and other nitrogenous waste in the blood resulting from kidney damage or failure.

Blepharospasm
A twitching or spasmodic contraction of eyelid.

Bradycardia
Abnormally slow heartbeat below a rate of 60 beats per minute.

Cachexia
A state of ill health, malnutrition and wasting.

Cardiac Arrhythmia
Absence of heartbeat.

Cardiac Dysrrhthmia
Irregular heartbeat.

Cardiac Ischemia
Abnormally low flow of blood to the heart.

Chloracne
Acne-like disruptions over the body resulting from exposure to certain chlorinated hydrocarbons such as dioxins.

Cholestasis
Blockage of the flow of bile resulting in increases of bilirubin in the blood.

Cyanosis
Bluish discoloration of the skin resulting from a deficiency of oxygen in the blood.

Desquamation
Shedding of outer layer of skin.

Dysphagia
Difficulty in swallowing.

Dysphonia
Difficulty in speaking; hoarseness.

Epigastric
Refers to the upper central portion of the abdomen between the lower ribs and the umbilicus (belly button).

Epistaxis
Nose bleed.

Erythemia
Redness of the skin.

Gastroenteritis
Inflammation of the stomach and intestines, usually accompanied by vomiting and diarrhea.

Hematuria
Blood in the urine.

Hemoglobinuria
The presence of hemoglobin the urine.

Hemolytic Anemia
Abnormal destruction of red blood cells resulting in a decrease in the number of cells in the blood and presence of free hemoglobin, which can lead to acute renal failure.

Hemoptysis
Spitting of blood arising from hemorrhage of the larynx, trachea, bronchial tubes, or lungs.

Hyperplasia
Abnormal but non-cancerous increase in the number of cells in a tissue or organ.

Hypertension
Elevated blood pressure.

Hyperthermia
Elevated body temperature.

Hypotension
Reduced blood pressure.

Hypothermia
Decreased body temperature.

Hypoxemia
Insufficient oxygenation of the blood.

Immunosuppression
Suppression of the immunologica response, leading to decreased resistance to disease.

Jaundice
A yellow staining or darkening of the skin, whites of the eyes, and excreta due to increased bile pigments in the blood and tissues.

Lassitude
Lethargy, apathy, exhaustion.

Leukopenia
Reduction in number of circulating white blood cells (the cells which fight infection).

Malaise
Discomfort, uneasiness indicative of infection or other disease.

Methemoglobinemia
Condition in which the oxidation state of iron in hemoglobin is abnormal leading to decreased availability of oxygen to the body tissues.

Miosis
Contraction of the pupil (pin-pointed pupil).

Monocytosis
Excessive number of monocytes (a type of white blood cell) in the blood.

Mucosa
Mucous membrane; membrane lining bodily channels that communicate with air (i.e., mouth, respiratory tract, eye); glands of mucous membranes secrete mucous.

Mydriasis
Dilation of the pupil.

Narcosis
Stupor or deep unconsciousness; can be caused by exposure to a number of chemicals. Differs from anesthesia which refers to the loss of sensation (e.g., pain) or touch and can be local or general.

Nephritis
Inflammation of the kidney.

Pallor
Paleness of the skin.

Palpitation
Perceptible irregular or rapid beating or pulsation of the heart.

Paresthesia
Burning prickling, tingling, or tickling sensation.

Paroxysmal
Recurring in sudden, periodic attacks or intensification of symptoms of a disease.

Photophobia
Unusual intolerance to light.

Polyneuropathy
Disease involving a number of peripheral nerves (e.g., nerves in the hands, feet or legs).

Porphyria Cutanea Tarda
A metabolic disorder in which reddish pigments or porphyrins are produced in the liver. The excess pigments accumulate in the skin where they are activated by visible light which causes photosensitive skin reactions characterized by skin erosions and blistering. These painful sores resolve slowly and may result in scarring, hair loss, and skin atrophy. Excess porphyrins are excreted in the urine which becomes colored dark red or brown as a result.

Precordial
Pertaining to the region over the heart and lower part of the thorax.

Prostration
Marked loss of strength; exhaustion.

Pulmonary Edema
Buildup of fluid in the lung.

Retrosternal
Behind the sternum.

Spasticity
Hypertonicity of muscles causing stiff and awkward movements.

Spermatogenesis
Development of sperm cells.

Stenosis
Constriction or narrowing of a passage or orifice.

Syncope
A transient form of unconsciousness during which the person slumps to the ground resulting from cerebral anoxia (insufficient oxygen in the brain).

Tachycardia
Excessively rapid heartbeat.

Tinnitus
Noise (typically ringing) in the ears.

Urogenital tract
Denotes the organs involved in reproduction and urination.

Ventricular Fibrillation
Rapid contractions or twitching of the muscle fibers that replace normal contraction of the ventricular chambers of the heart.

Vertigo
Dizziness; sense of spinning.

Vesiculation
Formation of a small blister-like small elevation on the skin containing serous fluid.

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Acronyms

ABS	Skin Absorption Factor
ACGIH	American Conference of Governmental Industrial Hygienists
AF	Adherence Factor
AMEDD	Army Medical Department
AO	Area of Operation
AQI	Air Quality Index
ARNG	Army National Guard
AT	Annual Training
ATSDR	Agency for Toxic Substances and Disease Registry
BAP	Benzo(a)pyrene
BC	Base Camp
BDU	Battle Dress Uniform
BUN	Blood Urea Nitrogen
BW	Body Weight
CHID	Chemical Hazard Information for Deployments
ChE Inh	Cholinesterase Inhibitor
cm^2	square centimeter
cm^3	Cubic centimeter
CNS	Central Nervous System
CO	Carbon Monoxide
COA	Course of Action
CONUS	Continental United States
cPAHs	Carcinogen Polycyclic Aromatic Hydrocarbons
CRC	Circulatory System

CS	Case Study
CSFi	Carcinogen Inhalation Slope Factor
CVS	Cardiovascular System
CWA	Chemical Warfare Agent
DA	Department of the Army
DESP	Deployment Environmental Surveillance Program
DNBI	Disease and Non-Battle Injury
DOD	Department of Defense
DODI	Department of Defense Instruction
ED	Exposure Duration
EEG	Electroencephalogram
EF	Exposure Frequency
EKG	Electrocardiogram
ENDO	Endocrine System
FDWS	Field Drinking Water Standards
FHP	Force Health Protection
FM	Field Manual
GI	Gastrointestinal
gm	gram
g/kg	gram per kilogram
g/L	gram per Liter
GPL	General Population Limit
HC	Hexachloroethane
HEAST	Health Effects Assessment Summary Tables
HEM	Hemopoietic System

HQDA	Headquarters Department of the Army
hr	Hour
HSDB	Hazardous Substance Databank
IDLH	Immediately Dangerous to Life and Health
IMM	Immune System
IOM	Institute of Medicine
IPB	Intelligence Preparation of the Battlefield
IRIS	Integrated Risk Information System
kg	kilogram
L	Liter
L/day	Liters/day
LC_{50}	Lethal Concentration for 50 percent of the exposed population
LC_{01}	Lethal Concentration for 1 percent of the exposed population
LD	Lethal Dose
LD_{50}	Lethal Dose for 50 percent of the exposed concentration
LD_{LO}	Lethal Dose –low (approximate low percentage e.g. 1-5%) lethalities amongst exposed
LOAEL	Lowest-Observed Adverse Effect Level
LOEL	Lowest-Observed Effect Level
LOG	Logistics
LRS	Lower Respiratory System
MEGs	Military Exposure Guidelines
METT-TC	Mission, Enemy, Terrain and Weather, Troops, Time, Civilian
MRL	Minimal Risk Level
Min	Minimal
m^3/day	cubic meter per day

?g/dl	microgram per decaliter
?g/kg	microgram per kilogram
?g/L	microgram per Liter
mg	milligram
mg/cm^2	milligram per square centimeter
mg/day	milligram per day
mg/kg	milligram per kilogram
mg/kg/day	milligram per kilogram per day
mg/L	milligram per Liter
mg/m^3	milligram per cubic meter
ml	milliliter
µm	micrometer
NAAQS	National Ambient Air Quality Standards
NBC	Nuclear, Chemical, Biological
NCO	Non-commissioned Officer
ND	Not determined
NO_2	Nitrogen Dioxide
NOAEL	No-Observable Adverse Effect Level
NRC	National Research Council
NTU	Nephelometric Turbidity Units
O_3	Ozone
OCONUS	Outside the Continental United States
OEH	Occupational and Environmental Health
OPORD	Operation Order
OPLAN	Operation Plan

ORM	Operational Risk Management
OSHA	Occupational Safety and Health Administration
PAH	Polycyclic Aromatic Hydrocarbons
Pb	Lead
PCB	Polychlorinated Biphenols
PEGL	Permissible Exposure Guidelines Level
PEL	Permissible Exposure Limit
PM	Particulate Matter
PNS	Peripheral Nervous System
PPE	Personal Protective Equipment
ppb	parts per billion
ppm	parts per million
QSTAG	Quadripartite Standardization Agreement
RBC	Risk Based Concentration
RD	Reference Document
Recon	Reconnaissance
RfC	Reference Concentration
RO	Reverse Osmosis
ROWPU	Reverse Osmosis Water Purification Unit
RS	Respiratory System
SA	Surface Area
SASO	Stability and Support Operations
Sev	Severe
SGOT	Serum glutamic-oxaloacetic transaminase
SGPT	Serum glutamate pyruvate transaminase

Sig	Significant
SO_2	Sulfur Dioxide
SOH	Safety and Occupational Health
STANAG	Standardization Agreement
TB MED	Technical Bulletin, Medical
TEF	Toxicity Equivalence Factor
TG	Technical Guide
TICs	Toxic Industrial Chemicals
TLVs	Threshold Limit Values
TON	Threshold Odor Number
TPH	Total Petroleum Hydrocarbons
TSCA	Toxic Substance Control Act
TT	Treatment Technique
TWA	Time-Weighted Average
TWPS	Tactical Water Purification System
UD	Under Development
UF	Uncertainty Factor
URS	Upper Respiratory System
USACHPPM	U.S. Army Center for Health Promotion and Preventive Medicine
USEPA	U.S. Environmental Protection Agency
UT	Urogenital Tract
WOE	Weight-of-Evidence
WPL	Worker Population Limit
WQAS-PM	Water Quality Analysis Set-Preventive Medicine
yr	Year
$ZnCl_2$	Zinc Chloride

APPENDIX C

MILITARY EXPOSURE GUIDELINES FOR AIR

CONTENTS

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TABLE C-1. AIR MILITARY EXPOSURE GUIDELINES FOR CHEMICAL WARFARE AGENTS

Chemical CAS No.	Air-MEG Health Effect Level	10-Minute mg/m^3 [ppm]	1-Hour mg/m^3 [ppm]	8-Hour mg/m^3 [ppm]	24-Hour mg/m^3 [ppm]	Potential Symptoms and Target Organs/Systems	Notes
GA (Tabun) 77-81-6	MINIMAL	0.0069 [0.0010]	0.0028 [0.00042]	0.0010 [0.00015]	0.0003 [0.00005]	Running nose; tightness of chest; miosis and dim vision; difficulty breathing; drooling and excessive sweating; nausea, vomiting; CNS effects. Local effects to pupil of the eye; Respiratory system, CNS	Based on relative potency from GB (see text for more information); (EPA 2001) 24-hour MEG estimate derived from 8-hour AEGL by straight-line extrapolation of 8-hour AEGL Ct (see EPA 2001 and document text) Existing (Recommended) IDLH = 0.2 (0.1) mg/m^3
	SIGNIFICANT	0.087 [0.013]	0.035 [0.0053]	0.013 [0.0020]	0.004 [0.00067]		
	SEVERE	0.76 [0.11]	0.26 [0.039]	0.10 [0.015]	0.03 [0.005]		

Chemical CAS No.	Air-MEG Health Effect Level	10-Minute mg/m^3 [ppm]	1-Hour mg/m^3 [ppm]	8-Hour mg/m^3 [ppm]	24-Hour mg/m^3 [ppm]	Potential Symptoms and Target Organs/Systems	Notes
GB (Sarin) 107-44-8	MINIMAL	0.0069 [0.0012]	0.0028 [0.00048]	0.0010 [0.00017]	0.0003 [0.000057]	Running nose; tightness of chest; dimness of vision and miosis; difficulty in breathing; drooling and excessive sweating; nausea, vomiting; cramps and involuntary defecation or urination; twitching, jerking and staggering; headache, confusion, drowsiness; at high exposures, coma and convulsion, leading to cessation of breathing and death	Minimal Level: Reversible miosis, headache, eye pain, rhinorrhea, tightness in chest, cramps, nausea, malaise, miosis in human volunteers; may limit performance for night operations, aircrews, and tasks involving distance or spatial judgment Significant Level: Reversible miosis, dyspnea, Red blood cell(RBC)-ChE inhibition, single fibre electromyography (SFEMG) changes in human volunteers; may limit performance for night operations, aircrews, and tasks involving distance or spatial judgment Severe Level: Based on GB vapor experimental Sprague-Dawley rat lethality data (LC_{01}, LC_{50}) (see text for more information); (USEPA 2001) Existing (Recommended) IDLH = 0.2 (0.1) mg/m^3
	SIGNIFICANT	0.087 [0.015]	0.035 [0.0060]	0.013 [0.0022]	0.004 [0.00073]		
	SEVERE	0.38 [0.064]	0.13 [0.022]	0.051 [0.0087]	0.02 [0.0029]	Local effects to pupil of the eye; Respiratory system, CNS, gastrointestinal system	

Chemical CAS No.	Air-MEG Health Effect Level	10-Minute mg/m^3 [ppm]	1-Hour mg/m^3 [ppm]	8-Hour mg/m^3 [ppm]	24-Hour mg/m^3 [ppm]	Potential Symptoms and Target Organs/Systems	Notes
GD (Soman) 96-64-0	MINIMAL	0.0035 [0.00046]	0.0014 [0.00018]	0.00050 [0.000065]	0.0002 [0.000022]	See GB for Symptoms.	Based on relative potency from GB (see text for more information); (USEPA 2001) 24-Hour MEG derived from 8-hour AEGL by straight-line extrapolation of 8-hour AEGL Ct (see USEPA 2001 and document text) Existing (Recommended) IDLH = 0.06 (0.05) mg/m^3
	SIGNIFICANT	0.044 [0.0057]	0.018 [0.0022]	0.0065 [0.00085]	0.002 [0.00028]	Local effects to pupil of the eye; Respiratory system, CNS, gastrointestinal system	
	SEVERE	0.38 [0.049]	0.13 [0.017]	0.051 [0.0066]	0.02 [0.0022]		
GF 329-99-7	MINIMAL	0.0035 [0.00049]	0.0014 [0.00020]	0.00050 [0.000070]	0.0002 [0.000023]	See GB for Symptoms.	Based on relative potency from GB (see text for more information); (USEPA 2001) 24-Hour MEG derived from 8-hour AEGL by straight-line extrapolation of 8-hour AEGL Ct (see USEPA 2001 and document text) (Recommended) IDLH = (0.05) mg/m^3 (no previous existing estimate)
	SIGNIFICANT	0.044 [0.0062]	0.018 [0.0024]	0.0065 [0.00091]	0.002 [0.00030]	Local effects to pupil of the eye; respiratory system, CNS, gastrointestinal system	
	SEVERE	0.38 [0.053]	0.13 [0.018]	0.051 [0.0071]	0.02 [0.0024]		

Chemical CAS No.	Air-MEG Health Effect Level	10-Minute mg/m^3 [ppm]	1-Hour mg/m^3 [ppm]	8-Hour mg/m^3 [ppm]	24-Hour mg/m^3 [ppm]	Potential Symptoms and Target Organs/Systems	Notes
Sulfur mustard [HD] 505-60-2	MINIMAL	0.40 [0.06]	0.067 [0.01]	0.008 0.001	0.003 [0.00033]	Delayed development of irritation to eyes, mucous membranes; potent alkylating agent; mutagenic. Conjunctivitis, blindness, edema of eyelids; necrosis of respiratory tract and exposed skin; nausea, vomiting[H]. Eyes, respiratory system, skin	24-Hour MEG estimate derived from 8-hour AEGL by straight-line extrapolation of 8-hour AEGL Ct (see NRC, in press - 2002) Existing (Recommended) GPL = 0.0001 (0.00002) mg/m³ Existing (Recommended) WPL = 0.003 (0.0004) mg/m³
	SIGNIFICANT	0.60 [0.09]	0.10 [0.02]	0.013 0.002	0.004 [0.00067]		
	SEVERE	3.9 [0.59]	2.1 [0.32]	0.27 [0.04]	0.09 [0.013]		

Chemical CAS No.	Air-MEG Health Effect Level	10-Minute mg/m³ [ppm]	1-Hour mg/m³ [ppm]	8-Hour mg/m³ [ppm]	24-Hour mg/m³ [ppm]	Potential Symptoms and Target Organs/Systems	Notes
VX 50782-69-9	MINIMAL	0.00020 [0.000018]	0.000080 [0.0000073]	0.000028 [0.0000026]	0.000009 [0.0000009]	AChE inhibitor; CNS effects: headache, runny nose and nasal congestion, nausea, vomiting, giddiness, anxiety, difficulty in sleeping/thinking, muscle twitching, weakness, abdominal cramps. Local effects to pupil of the eye; Respiratory system, CNS, gastrointestinal system	Minimal and Significant Levels: Derived by relative potency from study of multiple minimal (1) or transient (2) effects in human volunteers exposed to agent GB; may limit performance for night operations, aircrews, and tasks involving distance or spatial judgment Severe Level: Derived by relative potency from study of GB vapor experimental Sprague-Dawley rat lethality data (LC_{01}, LC_{50}) (USEPA 2001). 24-Hour MEG estimate derived from 8-hour AEGL by straight-line extrapolation of 8-hour AEGL Ct (see USEPA 2001 and document text) Existing (Recommended) GPL = 0.000003 (0.0000003) mg/m³ Existing (Recommended) WPL = 0.00001 (0.00001) mg/m³ Existing (Recommended) IDLH = 0.02 (0.01) mg/m³
	SIGNIFICANT	0.0024 [0.00022]	0.00098 [0.000090]	0.00035 [0.000032]	0.0001 [0.000011]		
	SEVERE	0.0096 [0.00088]	0.0033 [0.00030]	0.0013 [0.00012]	0.0004 [0.000040]		

Footnotes on next page.

FOOTNOTES FOR TABLE C-1 – AIR-MEGS FOR CHEMICAL WARFARE AGENTS

AchE: Acetylcholinesterase
AEGL: Acute Exposure Guideline Level
CNS: Central nervous system
Ct: Concentration ? time.
GPL: General population limit
IDLH: Immediately dangerous to life and health
WPL: Worker population limit
RBC – Red blood cell
ppm = part per million
mg/m^3 = milligrams per cubic meter

USEPA – U.S. Environmental Protection Agency. 2001. "National Advisory Committee for Acute Exposure Guideline Levels (AEGLs) for Hazardous Substances; Proposed AEGL Values" *Federal Register* 66 (85): 21940-21964 (2 May 2001).

National Research Council, Committee on Toxicology, Acute Exposure Guideline Levels (AEGLs) for Hazardous Substances, Volume 2; National Academy Press, in press - 2002

TABLE C-2. SHORT-TERM, AIR MILITARY EXPOSURE GUIDELINES (14 DAYS OR LESS)

Chemical CAS No.	1-Hour Air-MEG mg/m^3 [ppm]			8-Hour Air-MEG mg/m^3 [ppm]	14 Day Air-MEG mg/m^3 [ppm]	Potential Symptoms [N]	Target Organs and Systems [N]	Odor Threshold mg/m^3 [ppm] [?]	Notes
	Health Effect Level								
	Minimal	Significant	Severe						
Acetone Cyanohydrin 75-86-5	16.4[C] [4.7]	ND	ND	8 [2]	0.4 [0.1]	Irritation eyes, skin, respiratory system; dizziness, weakness, headache, confusion, convulsions; liver, kidney injury; pulmonary edema, asphyxia.	Eyes, skin, rs, CNS, CVS, liver, kidneys, GI tract	NA	Treatment of over exposure is for cyanide poisoning.
Acrolein 107-02-8	0.07 [0.03]	0.23 [0.1]	3.2 [1.4]	0.07 [0.03]	0.023 [0.01]	Irritation eyes, skin, mucous membrane; decreased pulmonary function; delayed pulmonary edema; chronic respiratory disease.	Eyes, skin, RS, heart	[0.022 – 1.8]	Pungent odor; concentrations of 0.06 ppm for 5 min caused irritation in humans.
Acrylonitrile 107-13-1	22 [10]	76 [35]	163 [75]	4.4 [2]	0.22 [0.10]	Irritation eyes, skin; asphyxia; headache; sneezing; nausea, vomiting; weakness, lightheadedness; skin vesiculation; scaling dermatitis.	Eyes, skin, CVS, liver, kidneys, CNS	[17]	Potential occupational carcinogen.
Aldrin 309-00-2	ND	ND	25	0.25[S] [0.02]	0.006[S] [0.0004]	Headache, dizziness; nausea, vomiting, malaise; limb jerks; convulsions; coma; hematuria: azotemia.	CNS, liver, kidneys, skin	0.25	Dermal exposures may contribute to total dose; potential occupational carcinogen.
Allyl alcohol 107-18-6	4.4 [1.8]	18.3 [7.7]	48 [20]	4.4[S] [1.8]	0.012[S] [0.05]	Eye irritation, tissue damage; irritation upper respiratory system, skin; pulmonary edema.	Eyes, skin, RS	[1.4 – 2.1]	Pungent, mustard-like odor. Dermal exposures may contribute to total dose.

Chemical CAS No.	1-Hour Air-MEG mg/m^3 [ppm] Health Effect Level Minimal	Significant	Severe	8-Hour Air-MEG mg/m^3 [ppm]	14 Day Air-MEG mg/m^3 [ppm]	Potential Symptoms [N]	Target Organs [N] and Systems	Odor? Threshold mg/m^3 [ppm]	Notes
Ammonia 7664-41-7	17 [25]	77 [110]	766 [1100]	17 [25]	0.35 [0.5]	Irritation eyes, nose, throat; difficulty breathing, bronchospasm; pulmonary edema; pink frothy sputum; skin burns.	Eyes, skin, RS	[17]	Pungent, suffocating odor.
Arsenic trichloride 7784-34-1	ND	ND	ND	0.01* [0.003]	0.01* [0.003]	Irritation of nose and throat[R].	Eyes, RS	NA	1-14 day value based on inorganic arsenic. *Measured as arsenic. CHID under development.
Arsine 7784-42-1	NA	0.54 [0.17]	1.6 [0.5]	0.17 [0.05]	0.004 [0.0012]	Headache, malaise; difficulty breathing; nausea, vomiting; bronze skin; hematuria; jaundice.	Blood, liver, kidneys	[0.5]	Disagreeable, garlic-like odor.
Benzene 71-43-2	160 [50]	479 [150]	3195 [1000]	1.6 (0.5)	0.16 [0.05]	Irritation eyes, skin, nose, respiratory system; giddiness; headache, nausea, staggered gait; fatigue, loss of appetite, lassitude (weakness, exhaustion); dermatitis; bone marrow depressant/depression.	Eyes, skin, RS, blood, CNS, bone	[34 119]	Aromatic odor; chronic exposures to low concentrations causes bone marrow depression; known carcinogen. CHID under development.
Boron tribromide 10294-33-4	10[C] [1]	ND	ND	10[C] [1]	10[C] [1]	Irritation eyes, skin, respiratory system; dyspnea, pulmonary edema.	Eyes, skin, RS	NA	
Boron trifluoride 7637-07-2	2 [0.73]	30 [11]	100 [36]	2 [0.73]	2 [0.73]	Irritation eyes, skin, nose, respiratory system; epistaxis (nosebleed); eye, skin burns; pneumonia; kidney damage.	Eyes, skin, RS, kidneys	NA	Low 1-hr value based on NOAEL; 6-hr exposures to rats at 2.2 ppm 6

Chemical CAS No.	1-Hour Air-MEG mg/m^3 [ppm] Health Effect Level Minimal	Significant	Severe	8-Hour Air-MEG mg/m^3 [ppm]	14 Day Air-MEG mg/m^3 [ppm]	Potential Symptoms [N]	Target Organs [N] and Systems	Odor? Threshold mg/m^3 [ppm]	Notes
									hrs/d for 3 months produced slight signs of irritation.
Bromine 7726-95-6	0.16 [0.024]	1.6 [0.24]	56 [8.5]	0.063 [0.0095]	0.063 [0.0095]	Dizziness, headache; lacrimation, epistaxis; cough, pulmonary edema, pneumonia; abdominal pain, diarrhea; measle-like eruptions; eye, skin burns.	RS, eyes, CNS, skin	[0.05]	Suffocating odor; concentrations above 10 ppm causes severe upper respiratory irritation; 1.7 – 3.5 ppm produces severe choking; 30 ppm would be fatal in a short duration.
Bromine pentafluoride 7789-30-2	ND	ND	ND	0.7 [0.1]	0.7 [0.1]	Irritation eyes, skin, respiratory system; corneal necrosis; skin burns; difficulty breathing, pulmonary edema; liver, kidney injury.	Eyes, skin, RS, liver, kidneys	NA	Potential sensitizer.
Butyl isocyanate (n-) 111-36-4	0.04 [0.01]	0.2 [0.05]	4.1 [1]	ND	ND	Skin irritation, eczema, conjunctivitis [H].	Skin and eyes[H]	NA	Concentrations of 0.1 – 1 ppm produce irritation to the respiratory tract and mucous membranes.
Carbon disulfide 75-15-0	3 [1]	156 [50]	1557 [500]	3[S] [1]	0.76[S] [0.24]	Dizziness, headache, nervousness, loss of appetite, polyneuropathy, ocular changes, coronary heart disease, gastritis, kidney, liver injury, dermatitis, reproductive effects.	CNS, PNS, CVS, eyes, kidneys, liver, skin, REPR	[0.11]	Dermal exposures may contribute to total dose; sweet, ether-like odor.

Chemical CAS No.	1-Hour Air-MEG mg/m^3 [ppm] Health Effect Level Minimal	Significant	Severe	8-Hour Air-MEG mg/m^3 [ppm]	14 Day Air-MEG mg/m^3 [ppm]	Potential Symptoms [N]	Target Organs [N] and Systems	Odor Threshold mg/m^3 [ppm]	Notes
Carbon monoxide 630-08-0	229 [200]	286 [350]	572 [500]	28 [25]	0.70 [0.61]	Headache, rapid breathing, nausea, weakness, dizziness, confusion, hallucinations; cyanosis; depressant/depression S-T segment of electro-cardiogram, angina, syncope.	CVS, lungs, blood, CNS	NA	
Carbon tetrachloride 56-23-5	75 [12]	428 [68]	1070 [170]	32.5 [5.2]	1.3 [0.2]	Irritation eyes, skin; CNS depressant/depression; nausea, vomiting; liver, kidney injury; drowsiness, dizziness, incoordination.	CNS, eyes, lungs, liver, kidneys, skin.	[140 584]	Aromatic, ether-like odor; potential occupational carcinogen.
Carbonyl fluoride 353-50-4	ND	ND	ND	5 [2]	[0.05] 0.13	Irritation eyes, skin, mucous membrane, respiratory system; eye, skin burns; excessive tearing; cough, pulmonary edema, difficulty breathing.	Eyes, skin, RS, bone	NA	
Chlorine 7782-50-5	2.9 [1]	5.8 [2]	64 [22]	1.5 [0.5]	0.29 [0.1]	Burning of eyes, nose, mouth; excessive tearing, rhinorrhea; coughing, choking, substernal pain; nausea, vomiting; hypoxemia; dermatitis.	CNS, eyes, lungs, liver, kidneys, skin	[0.02 – 3.4]	Pungent, disagreeable odor; a concentration of 34 – 51 ppm has been reported to be fatal in 1 – 1.5 hours.
Chlorine trifluoride 7790-91-2	1.3 [0.35]	11.7 [3.1]	53 [14]	0.15 [0.04]	0.15 [0.04]	Respiratory irritation; in animals: excessive tearing, corneal ulcer; pulmonary edema.	Skin, eyes, RS	NA	ACGIH ceiling value - 0.1 ppm (0.4 mg/m^3)
Chloro-acetaldehyde 107-20-0	3.2[C] [1]	71 [22]	144 [45]	3.2[C] [1]	3.2[C] [1]	Irritation skin, eyes, mucous membrane; skin burns; eye damage; pulmonary edema; skin, respiratory system	Eyes, skin, RS	NA	Volunteers found that concentrations of 45 ppm were very disagreeable

Chemical CAS No.	1-Hour Air-MEG mg/m^3 [ppm] Health Effect Level Minimal	Significant	Severe	8-Hour Air-MEG mg/m^3 [ppm]	14 Day Air-MEG mg/m^3 [ppm]	Potential Symptoms [N]	Target Organs [N] and Systems	Odor [?] Threshold mg/m^3 [ppm]	Notes
						sensitization.			and conjunctival irritation was noted.
Chloroacetone 78-95-5	3.8[C] [1]	ND	ND	3.8[C] [1]	3.8[C] [1]	Excessive tearing, irritation skin and respiratory tract, pulmonary edema[H].	Eyes, skin, RS	NA	Concentration of 605 ppm is lethal after a 10 minute exposure and 26 ppm is intolerable after a 1 minute exposure.
Chloroaceto-phenone [CN] 532-27-4	ND	ND	15	0.32 [0.05]	0.32 [0.05]	Excessive tearing, irritation of the skin, rashes in tender skin areas of the armpits, knees, elbows, area of the crotch and buttocks[T].	Skin, eyes[T]	[0.016]	Floral to sharp, irritating odor with increasing concentration; concentration of 31 mg/m^3 is intolerable after 3 minutes.
Chloroacetyl chloride 79-04-9	0.23 [0.05]	2.3 [0.5]	46 [10]	0.23[S] [0.05]	0.23[S] [0.05]	Irritation eyes, skin, respiratory system; eye, skin burns; cough, wheezing, difficulty breathing; excessive tearing.	Eyes, skin, RS	NA	Dermal exposures may contribute to total dose.
Chlorobenzyli-denemalonitrile o- [CS] 2698-41-1	0.39[C] [0.05]	ND	2 [0.26]	0.39[C] [0.05]	0.39[C] [0.05]	Extremely irritating to the nose and throat with immediate lacrimatory effects; nausea and vomiting; shortness of breath, burning of the skin especially effecting the eyes, nose, mouth, and tender areas around the knees, elbows, crotch, and buttocks[T].	Eyes, skin, CNS, RS[T]	NA	Peppery odor; incapacitating concentration range from 12 – 20 mg/m^3 after 20 seconds of exposure.

Chemical CAS No.	1-Hour Air-MEG mg/m^3 [ppm] Health Effect Level Minimal	Significant	Severe	8-Hour Air-MEG mg/m^3 [ppm]	14 Day Air-MEG mg/m^3 [ppm]	Potential Symptoms [N]	Target Organs [N] and Systems	Odor? Threshold mg/m^3 [ppm]	Notes
Chloroform 67-66-3	NA	430 [88]	3174 [650]	48 [10]	0.5 [0.1]	Irritation eyes, skin; dizziness, mental dullness, nausea, confusion; headache, fatigue; anesthesia; enlarged liver.	Liver, kidneys, heart, eyes, skin, CNS.	[133-276]	Pleasant, ether-like odor; potential occupational carcinogen; disorientation occurs at concentrations exceeding 1000 ppm.
Crotonaldehyde 4170-30-3	0.54 [0.19]	12.6 [4.4]	40 [14]	0.54[S] [0.19]	0.54[S] [0.19]	Irritation of the eyes and respiratory system; in animals: difficulty breathing, pulmonary edema, skin irritation.	Eyes, skin, RS	[0.11]	Dermal exposures may contribute to total dose; pungent odor. 0.3 ppm[C]
Cyanogen 460-19-5	22 [20]	78 [71]	166 [150]	20 [10]	0.51 [0.24]	Irritation eyes, nose, upper respiratory system; excessive tearing; cherry red lips, bradycardia; headache, vertigo, convulsions; dizziness, loss of appetite, weight loss; smell of bitter almonds on breath.	Eyes, RS, CNS, CVS, blood	[235]	Based on cyanide. Inhibits cells ability to utilize oxygen; Persons with kidney/ respiratory (including asthma), skin or thyroid conditions at greater risk.
Diborane 19287-45-7	0.34 [0.3]	1.13 [1]	4.2 [3.7]	0.1 [0.1]	0.0024 [0.0024]	Chest tightness, precordial pain, shortness breathing, cough, nausea, headache, dizziness, fever, fatigue, weakness, tremor; liver, kidney damage, pulmonary edema and hemorrhage.	RS, CNS, liver, kidneys	[2.5]	Repulsive, sickly sweet odor.

Chemical CAS No.	1-Hour Air-MEG mg/m^3 [ppm] Health Effect Level Minimal	Significant	Severe	8-Hour Air-MEG mg/m^3 [ppm]	14 Day Air-MEG mg/m^3 [ppm]	Potential Symptoms [N]	Target Organs [N] and Systems	Odor Threshold mg/m^3 [ppm]	Notes
Dichloroethane (1,1-) 75-34-3	ND	ND	12,144 [3000]	400 [100]	9.8 [2.4]	Irritation skin; CNS depressant/ depression; liver, kidney, lung damage.	Skin, liver, kidneys, lungs, CNS	[100 – 200]	Odor threshold range broad: care should be used when attempting to estimate exposure from odor perception.
Dieldrin 60-57-1	0.75	1.25	50	0.25[S] [0.02]	0.006[S] [0.0004]	Headache, dizziness; nausea, vomiting, malaise, sweating; limb jerks; convulsions; coma; in animals: liver, kidney damage.	CNS, liver, kidneys, skin	NA	Dermal exposures may contribute to total dose. Potential occupational carcinogen.
Diesel fuel smoke	8	80	ND	5	5	Inflammation of lung, irritation of respiratory tract, congestion in nasal turbinate, bronchopneumonia, bronchitis, pulmonary congestion with edema and hemorrhage[M].	Lung, RS[M]	NA	
Diketene 674-82-8	3.4 [1]	17 [5]	69 [20]	NA	NA	Eye, skin, and respiratory tract irritation[H].	Eyes, skin, RS[H]	NA	
Dimethyl sulfate 77-78-1	1.5 [0.3]	5.2 [1]	36 [7]	0.5[S] [0.1]	0.0012[S] [0.0024]	Irritation eyes, nose; headache, giddiness; conjunctivitis; photophobia, edema; dysphonia, dysphagia, productive cough; chest pain; difficulty breathing, cyanosis; vomiting, diarrhea.	Eyes, skin, RS, liver, kidneys, CNS	NA	Dermal exposure may contribute to total dose.
Endrin 72-20-8	0.1[S] [0.008]	0.3 [0.024]	2 [0.16]	0.1[S] [0.008]	0.01[S] [0.00016]	Headache, dizziness; abdominal discomfort, nausea, vomiting, stupor, aggressiveness, confusion; lethargy (drowsiness or	CNS, liver	0.28	Dermal exposures may contribute to total dose – skin absorption should be avoided.

Chemical CAS No.	1-Hour Air-MEG mg/m^3 [ppm] Health Effect Level Minimal	Significant	Severe	8-Hour Air-MEG mg/m^3 [ppm]	14 Day Air-MEG mg/m^3 [ppm]	Potential Symptoms [N]	Target Organs [N] and Systems	Odor? Threshold mg/m^3 [ppm]	Notes
						indifference), weakness; epileptiform convulsions; insomnia; loss of appetite; in animals: liver damage.			Primary route of toxicity is through ingestion of contaminated media; will metabolize quickly.
Ethyl benzene 100-41-4	542 [125]	4342 [1000]	8684-21710 [2000-5000]	435 [100]	10.5 [2.4]	Irritation eyes, skin, mucous membrane; headache; dermatitis; narcosis, coma.	Eyes, skin, RS, CNS	[0.09 – 0.60]	Most severe irritant of benzene series; strong eye irritation/tear/with tolerance developing levels below 1000 ppm; at 2000 ppm intolerable eye effects. Aromatic odor.
Ethylenimine 151-56-4	2.64 [1.5]	8.1 [4.6]	17.4 [9.9]	0.92[S] [0.5]	0.022[S] [0.012]	Irritation eyes, skin, nose, throat; nausea, vomiting; headache, dizziness; pulmonary edema; liver, kidney damage; eye burns; skin sensitization.	Eyes, skin, RS, liver, kidneys	NA	Dermal exposures may contribute to total dose; ammonia-like odor.
Ethylene oxide 75-21-8	14 [7.5]	81 [45]	360 [200]	1.8 [1]	0.04 [0.02]	Irritation eyes, skin, nose, throat; peculiar taste; headache, nausea; vomiting, diarrhea; difficulty breathing, cyanosis, pulmonary edema; incoordination; EKG abnormalities.	Eyes, skin, RS, liver, CNS, blood, kidneys, REPR	[425]	Based on soluble tungsten; sweet olefininc odor; concentrations > 1 hr, at 2000 ppm may be fatal.
Fluorine 7782-41-4	3.1 [2]	7.8 [5]	20.2 [13]	1.6 [1]	1.6 [1]	Irritation eyes, nose, respiratory system; laryngeal	Eyes, skin, RS, liver, kidneys	[0.14]	Low value based on odor; repeated

Chemical CAS No.	1-Hour Air-MEG mg/m^3 [ppm]			8-Hour Air-MEG mg/m^3 [ppm]	14 Day Air-MEG mg/m^3 [ppm]	Potential Symptoms [N]	Target Organs [N] and Systems	Odor Threshold mg/m^3 [ppm]	Notes
	Health Effect Level								
	Minimal	Significant	Severe						
						spasm, bronchitis spasm; pulmonary edema; eye, skin burns; liver and kidney damage in animals.			exposure to 10 ppm was reported to be well-tolerated in workers; concentrations of 25 ppm have been tolerated briefly, yet two volunteers developed sore throats and chest pains that lasted 6 hrs; 50 ppm could not be tolerated.
Fog oil smoke	9	90	ND	5	5	Mild erythema, inflammation, dermatitis, acne, eczema, and contact sensitivity; pneumonia, cough, and phlegm[M].	Skin, lungs, RS[M]	NA	
Formaldehyde 50-00-0	1.2 [1]	12.3 [10]	31 [25]	0.37[C] [0.3]	0.37[C] [0.3]	Respiratory system irritation; excessive tearing; cough, bronchitis spasm.	Eyes, RS	[0.83]	Pungent, suffocating odor.
GA (Tabun) 77-81-6	See Table C-1								
GB (Sarin) 107-44-8	See Table C-1								
GD (Soman) 96-64-0	See Table C-1								

Chemical CAS No.	1-Hour Air-MEG mg/m³ [ppm] Health Effect Level Minimal	Significant	Severe	8-Hour Air-MEG mg/m³ [ppm]	14 Day Air-MEG mg/m³ [ppm]	Potential Symptoms [N]	Target Organs [N] and Systems	Odor Threshold mg/m³ [ppm]	Notes
GF 329-99-7	See Table C-1								
Hexachloro-butadiene 87-68-3	32 [3]	107 [10]	320 [30]	0.24[S] [0.02]	0.005[S] [0.0005]	In animals: irritation eyes, skin, respiratory system; kidney damage.	Eyes, skin, RS, kidneys	[1.1]	Dermal exposures may contribute to total dose; turpentine-like odor; potential occupational carcinogen; concentrations of 23 ppm (245 mg/m³) produced strong odors; 1 ppm (10 mg/m³), faint odor.
Hexachloro-cyclopentadiene 77-47-4	0.1 [0.01]	0.35 [0.03]	1.6 [0.15]	0.1 [0.01]	0.1 [0.01]	Irritation eyes, skin, respiratory system; excessive tearing; sneezing, cough, difficulty breathing, salivation, pulmonary edema; nausea, vomiting, diarrhea.	Eyes, skin, RS, liver, kidneys	[0.03]	Strong irritant with concentration threshold at 0.1 mg/m³ – at this point no longer duration dependant. Pungent, unpleasant odor.
Hexachloroethane (smoke) 67-72-1	0.3	3	ND	0.2	0.2	Acute respiratory distress syndrome, edema, difficulty breathing, chest constriction, retrosternal pain, hoarseness, cough, lacrimation	RS, lungs, eyes [M]	NA	Symptoms and target organ based on exposure to $ZnCl_2$, (zinc chloride) a

Chemical CAS No.	1-Hour Air-MEG mg/m³ [ppm] Health Effect Level Minimal	Significant	Severe	8-Hour Air-MEG mg/m³ [ppm]	14 Day Air-MEG mg/m³ [ppm]	Potential Symptoms [N]	Target Organs [N] and Systems	Odor? Threshold mg/m³ [ppm]	Notes
						expectoration, irritation of the nose, throat, and chest; nausea[M].			component released when smoke bomb is ignited.
Hexane 110-54-3	528 [150]	880 [250]	3872 [1100]	180[S] [50]	4.3[S] [1.2]	Irritation eyes, nose; lightheadedness; nausea, headache; peripheral neuropathy: numbness extremities, muscle weakness; dermatitis; giddiness; chemical pneumonia (aspiration liquid).	Eyes, skin, RS, CNS, PNS	[130]	Dermal exposures may contribute to total dose.
Hydrazine 302-01-2	0.13 [0.1]	17 [13]	46 [35]	0.13 [0.1]	0.013 [0.01]	Irritation eyes, skin, nose, throat; temporary blindness; dizziness, nausea; dermatitis; eye, skin burns; in animals: bronchitis, pulmonary edema; liver, kidney damage; convulsions.	Eyes, skin, RS, CNS, liver, kidneys	[3 - 4]	Potential carcinogen.
Hydrogen bromide 10035-10-6	9.9[C] [3]	19.8 [6]	99 [30]	9.9[C] [3]	9.9[C] [3]	Irritation eyes, skin, nose, throat.	Eyes, skin, RS	[2]	Strong irritant with concentration threshold at 9.9 mg/m³ – at this point no longer duration dependant. Sharp irritating odor; skin burns.
Hydrogen chloride 7647-01-0	2.7 [1.8]	33 [22]	155 [104]	2.7 [1.8]	2.7 [1.8]	Irritation nose, throat, larynx; cough, choking; dermatitis.	Eyes, skin, RS	[0.77]	Asthmatics may experience adverse effects above 3 ppm; concentrations of

Chemical CAS No.	1-Hour Air-MEG mg/m^3 [ppm] Health Effect Level Minimal	Significant	Severe	8-Hour Air-MEG mg/m^3 [ppm]	14 Day Air-MEG mg/m^3 [ppm]	Potential Symptoms [N]	Target Organs [N] and Systems	Odor Threshold mg/m^3 [ppm]	Notes
									35 ppm caused throat irritation; 50 – 100 ppm are barely tolerable.
Hydrogen cyanide 74-90-8	2.2 [2]	7.8 [7.1]	16.6 [15]	1.1[S] [1]	0.11[S] [0.11]	Asphyxia; weakness, headache, confusion; nausea, vomiting; increased rate and depth of respiration or respiration slow and gasping; thyroid, blood changes.	CNS, CVS, thyroid, blood	NA	Dermal exposures may contribute to total dose; sweetish, almond-like odor; concentrations of 45 – 54 ppm may be tolerable for 0.5 – 1.0 hr; 110 – 135 ppm may be fatal after 0.5 – 1.0 hr or later.
Hydrogen fluoride 7664-39-3	0.82 [1]	19.6 [24]	36 [44]	0.41 [0.5]	0.41 [0.5]	Irritation eyes, skin, nose, throat; pulmonary edema; eye, skin burns; rhinitis; bronchitis; bone changes.	Eyes, skin, RS, bones	[0.04]	Exposures of 2.7-4.7 ppm produced very slight irritation and was tolerated 6hrs/d for several days; concentrations of 50 ppm for 30 – 60 min may be fatal. volunteers tolerated 4.7 ppm for 6-hrs/ day for 10 – 50 days.

Chemical CAS No.	1-Hour Air-MEG mg/m^3 [ppm] Health Effect Level Minimal	Significant	Severe	8-Hour Air-MEG mg/m^3 [ppm]	14 Day Air-MEG mg/m^3 [ppm]	Potential Symptoms [N]	Target Organs [N] and Systems	Odor Threshold mg/m^3 [ppm]	Notes
Hydrogen selenide 7783-07-5	ND	ND	3.3 [1]	0.2 [0.05]	0.2 [0.05]	Irritation eyes, nose, throat; nausea, vomiting, diarrhea; metallic taste, garlic breathing; dizziness, lassitude, fatigue.	Eyes, RS, liver	NA	*Measured as selenium.
Hydrogen sulfide 7783-06-4	0.23 [0.17]	39 [28]	70 [50]	0.15 [0.11]	0.15 [0.11]	Irritation eyes, apnea, coma, convulsions; conjunctivitis, eye pain, lacrimation photophobia (abnormal visual intolerance to light), corneal vesiculation; dizziness, headache, fatigue, insomnia; gastrointestinal disturbance.	Eyes, RS, CNS	[0.001 – 0.13]	Rotten egg odor strong at concentrations above 0.1 ppm; concentrations of 170 to 300 ppm are the maximum tolerated concentrations for 1-hr without serious consequences; olfactory fatigue occurs at 100 ppm.
Iron pentacarbonyl 13463-40-6	ND	1.5 [0.19]	4.6 [0.58]	0.8 [0.1]	0.02 [0.0024]	Irritation eyes, mucous membrane, respiratory system; headache, dizziness, nausea, vomiting; fever, cyanosis, difficulty breathing; liver, kidney, lung injury; degenerative changes in CNS.	Eyes, RS, CNS, liver, kidneys	NA	* Measured as iron.
Lewisite 541-25-3	0.003[C] [0.00035]	ND	ND	0.003[C] [0.00035]	0.003[C] [0.00035]	Immediate pain in the eyes, resulting in profuse tearing and blepharospasm; pulmonary irritant, erythema, pulmonary edema[H].	Eyes, RS[H]	NA	See Table C-1
Lindane 58-89-9	1.5 [0.126]	50 [4.2]	50 [4.2]	0.5[S] [0.04]	0.012[S] [0.001]	Irritation eyes, skin, nose, throat; headache; nausea;	Eyes, skin, RS, CNS, blood, liver,	NA	Dermal exposures may contribute to

Chemical CAS No.	1-Hour Air-MEG mg/m³ [ppm] Health Effect Level: Minimal	Significant	Severe	8-Hour Air-MEG mg/m³ [ppm]	14 Day Air-MEG mg/m³ [ppm]	Potential Symptoms [N]	Target Organs [N] and Systems	Odor [?] Threshold mg/m³ [ppm]	Notes
						convulsions; respiratory difficulty; cyanosis; aplastic anemia; muscle spasm; in animals: liver, kidney damage.	kidneys		total dose; 2 & 3 values based on oral data.
Methyl bromide 74-83-9	58.3 [15]	195 [50]	777 [200]	4[S] [1]	0.09[S] [0.024]	Irritation eyes, skin, muscle weakness, visual disturbance, dizziness; nausea, vomiting, headache; malaise; hand tremor; convulsions; difficulty breathing; skin vesiculation.	Eyes, skin, RS, CNS	NA	Dermal exposures may contribute to total dose.
Methylene chloride 75-09-2	695 [200]	2600 [750]	13,880 [4000]	175 [50]	2.1 [0.6]	Irritation eyes, skin; fatigue, weakness, somnolence (sleepiness, unnatural drowsiness), lightheadedness; numbness, limbs tingle, nausea.	Eyes, skin, CVS, CNS	[160]	Sweet, chloroform-like odor; potential occupational carcinogen.
Methyl hydrazine 60-34-4	ND	1.9 [1]	5.7 [3]	0.02[S] [0.01]	0.0005[S] [0.00024]	Irritation eyes, skin, respiratory system; vomiting, diarrhea, tremor, ataxia; anoxia, cyanosis; convulsions.	Eyes, skin, RS, CNS, liver, blood, CVS	[1.7]	Dermal exposures may contribute to total dose.
Methyl isocyanate 624-83-9	0.06 [0.025]	0.16 [0.067]	0.47 [0.2]	0.05[S] [0.02]	0.05[S] [0.02]	Irritation eyes, skin, nose, throat; respiratory sensitization, cough, pulmonary secretions, chest pain, difficulty breathing; asthma; eye, skin damage.	Eyes, skin, RS	[2.1]	Dermal exposures may contribute to total dose; sharp, pungent odor.
Methyl mercaptan 74-93-1	1 [0.5]	9.7 [5]	45 [23]	1 [0.5]	0.024 [0.012]	Irritation eyes, skin, respiratory system; narcosis; cyanosis; convulsions.	Eyes, skin, RS, CNS, blood	[0.0016]	Odor of rotten cabbage significant at concentrations above 0.005 ppm; odor fatigue occurs with time.

Chemical CAS No.	1-Hour Air-MEG mg/m^3 [ppm] Health Effect Level			8-Hour Air-MEG mg/m^3 [ppm]	14 Day Air-MEG mg/m^3 [ppm]	Potential Symptoms [N]	Target Organs and Systems [N]	Odor Threshold mg/m^3 [ppm] [?]	Notes
	Minimal	Significant	Severe						
Nitric acid 7697-37-2	1.3 [0.5]	10 [4]	57 [22]	1.3 [0.5]	1.3 [0.5]	Irritation eyes, skin, mucous membrane; delayed pulmonary edema, pneumonititis, bronchitis; dental erosion.	Eyes, skin, RS	[0.3]	
Nitric oxide 10102-43-9	0.61* [0.5]	15* [12]	25* [20]	0.61* [0.5]	0.61* [0.5]	Irritation eyes, wet skin, nose, throat; drowsiness, unconsciousness; methemoglobinemia.	Eyes, skin, RS, blood, CNS	[0.3]	*Values for NO are based on NO_2 toxicity since NO converts to NO_2 in the atmosphere. No hazard associated with short-term exposure to 80 ppm.
Nitrogen dioxide 10102-44-0	0.94 [0.5]	23 [12]	38 [20]	0.94 [0.5]	0.94 [0.5]	Irritation eyes, nose, throat, cough, mucoid frothy sputum, decreased pulmonary function, difficulty breathing; chest pain; pulmonary edema, cyanosis, rapid breathing, tachycardia.	Eyes, RS, CVS	[1.06]	CHID is under development.
Paraquat 4685-14-7	0.15 [0.024]	1.0 [0.16]	*	0.1 [0.016]	0.01 [0.0016]	Irritation eyes, skin, nose, throat, respiratory system; epistaxis; dermatitis; fingernail damage; irritation gastrointestinal tract; heart, liver, kidney damage.	Eyes, skin, RS, heart, liver, kidneys, GI tract	NA	* Must be aerosolized to inhale –only brief inhalation exposures expected; severe effects toxicity data is limited to primary route of ingestion - MEG toxicity based on

Chemical CAS No.	1-Hour Air-MEG mg/m³ [ppm] Health Effect Level Minimal	 Significant	 Severe	8-Hour Air-MEG mg/m³ [ppm]	14 Day Air-MEG mg/m³ [ppm]	Potential Symptoms [N]	Target Organs [N] and Systems	Odor? Threshold mg/m³ [ppm]	Notes
									particle size (see RD 230). 1.5 mg/m³ = IDLH; 0.5= TWA for total dust; 0.1 TWA for respirable fraction.
Parathion 56-38-2	0.3 [0.024]	2 [0.16]	10 [0.8]	0.1 [0.008]	0.0024 [0.0002]	Irritation eyes, skin, respiratory system; miosis; rhinorrhea; headache; chest tightness, wheezing, laryngeal spasm, salivation, cyanosis; anorexia, nausea, vomiting, abdominal cramps, diarrhea; sweating; muscle fasiculation, weakness, paralysis; giddiness, confusion, ataxia; convulsions, coma; low blood pressure; cardiac irregular/irregularities.	Eyes, skin, RS, CNS, CVS, blood ChE Inh	[0.04]	
Perchloro-methyl mercaptan 594-42-3	0.11 [0.014]	0.27 [0.035]	2.3 [0.3]	0.05 [0.006]	0.05 [0.006]	Irritation eyes, skin, nose, throat; lacrimation; cough, difficulty breathing, deep breathing pain, coarse rales; vomiting; pallor, tachycardia; acidosis; anuria; liver, kidney damage.	Eyes, skin, RS, liver, kidneys	[0.001]	
Phosgene 75-44-5	0.4 [0.1]	1.2 [0.3]	3.0 [0.75]	0.4 [0.1]	0.04 [0.01]	Irritation eyes; dry burning throat; vomiting; cough, foamy sputum, difficulty breathing, chest pain, cyanosis.	Eyes, skin, respiratory system	[0.5]	Lethality may occur at lower concentrations (5 ppm) due to pulmonary edema.
Phosphine 7803-51-2	NA	0.42 [0.3]	1.5 [1.1]	0.4 [0.3]	0.01 [0.0073]	Nausea, vomiting, abdominal pain, diarrhea; thirst; chest	CNS, RS	[0.9]	Disagreeable odor of rotten fish or

Chemical CAS No.	1-Hour Air-MEG mg/m³ [ppm] Health Effect Level: Minimal	Significant	Severe	8-Hour Air-MEG mg/m³ [ppm]	14 Day Air-MEG mg/m³ [ppm]	Potential Symptoms [N]	Target Organs and Systems [N]	Odor Threshold mg/m³ [ppm] [?]	Notes
						tightness, difficulty breathing, muscle pain, chills; stupor or syncope; pulmonary edema.			garlic; concentrations up to 35 ppm have caused diarrhea, nausea, vomiting, cough, headache, and dizziness.
White phosphorus (yellow) 7723-14-0	0.3 [0.06]	3 [0.59]	5 [0.99]	0.1 [0.02]	0.0024 [0.0005]	Irritation eyes, respiratory tract; eyes, skin burns; abdominal pain, nausea, jaundice; anemia; cachexia; dental pain, salivation, jaw pain, swelling.	Eyes, skin, RS, liver, kidneys, blood, bone	NA	
Phosphorus oxychloride 10025-87-3	ND	ND	5.3 [0.85]	0.6 [0.1]	0.015 [0.002]	Irritation eyes, skin, respiratory system; eye, skin burns; difficulty breathing, cough, pulmonary edema; dizziness, headache, weakness; abdominal pain, nausea, vomiting; nephritis.	Eyes, skin, RS, CNS, kidneys	NA	
Phosphorus trichloride 7719-12-2	ND	ND	4.9 [0.87]	1.5 [0.27]	1.5 [0.27]	Irritation eyes, skin, nose, throat; pulmonary edema; eye, skin burns.	Eyes, skin, RS	NA	Concentrations of 1.8 – 27 ppm have been reported to produce burning of the eyes and throat, and mild bronchitis within 2 – 6 hrs after exposure.
Red phosphorus smoke	1	10	1000	1	1	Irritation eyes, respiratory tract; eye, skin burns; abdominal pain, nausea, jaundice; anemia; cachexia;	Eyes, skin, RS, liver, kidneys, bone, blood	NA	

Chemical CAS No.	1-Hour Air-MEG mg/m³ [ppm] Health Effect Level Minimal	Significant	Severe	8-Hour Air-MEG mg/m³ [ppm]	14 Day Air-MEG mg/m³ [ppm]	Potential Symptoms [N]	Target Organs and Systems [N]	Odor Threshold mg/m³ [ppm] [?]	Notes
						dental pain, salivation, jaw pain, swelling.			
Selenium hexa-fluoride 7783-79-1	1.2 [0.15]	2 [0.25]	16 [2]	0.4 [0.05]	0.4 [0.05]	Pulmonary irritation, edema.	RS		*Measured as selenium.
Stibine 7803-52-3	ND	2.6 [0.5]	7.7 [1.5]	0.5 [0.1]	0.5 [0.1]	Headache, weakness; nausea, abdominal pain; lumbar pain, hemoglobinuria, hematuria, hemolytic anemia; jaundice; pulmonary irritation.	Blood, liver, kidneys, RS	NA	
Sulfur dioxide 7446-09-5	ND	8 [3]	39 [15]	5 [2]	2.6 [1]	Irritation eyes, nose, throat; rhinorrhea (discharge of thin nasal mucus); choking, cough; reflex bronchoconstriction.	Eyes, skin, RS	[1.1]	Metallic taste, sharp. Asthmatics may experience reduced airway resistance above 0.3 ppm. CHID under development.
Sulfur mustard [HD] 505-60-2	See Table C-1								
Sulfuric acid 7664-93-9	2 [0.5]	10 [2.5]	30 [7.5]	1 [0.25]	1 [0.25]	Severe lung damage; loss of vision; corrosion of mucous membranes; nausea, vomiting.	RS	1	Carcinogen; lung.
Sulfuryl fluoride 2699-79-8	ND	ND	835 [200]	20 [5]	0.5 [0.12]	Conjunctivitis, rhinitis, pharyngitis, paresthesia; liquid; frostbite: in animals: narcosis, tremor, convulsions; pulmonary edema; kidney injury.	Eyes, skin, RS, CNS, kidneys	NA	
Tellurium hexafluoride 7783-80-4	0.6 [0.06]	10 [1]	**	0.2 [0.02]	0.2 [0.02]	Results in bluish black coloration of webs of fingers/streaks on face;	RS	NA	Measured as tellurium. Suggestion of

Chemical CAS No.	1-Hour Air-MEG mg/m³ [ppm] Health Effect Level: Minimal	Significant	Severe	8-Hour Air-MEG mg/m³ [ppm]	14 Day Air-MEG mg/m³ [ppm]	Potential Symptoms [N]	Target Organs [N] and Systems	Odor Threshold mg/m³ [ppm]	Notes
						possible smell of garlic from sweat/breathing; headache; difficulty breathing; in animals: pulmonary edema			tolerance – mild effects may dissipate after prolonged exposure. ** Not clear at what level human fatalities or true severe effects would occur (just greater than 1 ppm)
Tetrachloro-ethane (1,1,2,2-) 79-34-5	20.6 [3]	34.3 [5]	686 [100]	7 [1]	0.2 [0.024]	Nausea, vomiting, abdominal pain; tremor fingers; jaundice, hepatitis; monocytosis (increased blood monocytes); kidney damage.	Skin, liver, kidneys, CNS, GI tract	[3]	Pungent chloroform-like odor; potential occupational carcinogen.
Tetrachloro-ethylene 127-18-4	237 [35]	1560 [230]	3323 [490]	81 [12]	4.2 [0.61]	Irritation eyes, skin, nose, throat, respiratory system; nausea; flush face, neck; vertigo (an illusion of movement), dizziness, incoordination; headache, somnolence (sleepiness, unnatural drowsiness); skin erythema (skin redness); liver damage.	Eyes, skin, RS, liver, kidneys, CNS	[47]	Mild chloroform-like odor; potential occupational carcinogen.
Tetraethyl lead 78-00-2	0.13 [0.01]	0.75 [0.06]	4.0 [0.30]	0.1[S] [0.013]	0.0024[S] [0.0003]	Insomnia, lassitude, anxiety; tremor, hyper-reflexia, spasticity; bradycardia, hypotension, hypothermia, pallor, nausea, loss of appetite, weight loss; confusion,	CNS, CVS, kidneys, eyes	NA	*Measured as total Pb (no speciation); guideline based on most toxic Pb species.

Chemical CAS No.	1-Hour Air-MEG mg/m^3 [ppm] Health Effect Level			8-Hour Air-MEG mg/m^3 [ppm]	14 Day Air-MEG mg/m^3 [ppm]	Potential Symptoms [N]	Target Organs [N] and Systems	Odor? Threshold mg/m^3 [ppm]	Notes
	Minimal	Significant	Severe						
						hallucinations, psychosis, mania, convulsions, coma; eye irritation.			
Tetramethyl lead 75-74-1	ND	ND	40	0.1[S] [0.013]	0.0024[S] [0.0003]	Insomnia, restlessness, anxiety; hypotension; nausea, loss of appetite; delirium, mania, convulsions; coma.	CNS, CVS, kidneys	NA	*Measured as total Pb (no speciation); guideline based on most toxic Pb species.
Titanium tetrachloride 7550-45-0	5 [0.64]	20 [2.6]	100 [12.9]	0.5 [0.064]	0.012 [0.0015]	Cornea damage, congestion of the mucous membrane of the pharynx, vocal cords, and trachea; stenosis of larynx, trachea and upper bronchi; skin irritation[H].	Skin, eyes, URS[H]	NA	
Toluene 108-88-3	309 [82]	716 [190]	2374 [630]	109 [29]	11 [3]	Irritation eyes, nose; fatigue, weakness, confusion, euphoria, dizziness, headache; dilated pupils, excessive tearing; nervousness, muscle fatigue, insomnia; paresthesia; dermatitis; liver, kidney damage.	Eyes, skin, RS, CNS, liver and kidneys	[2.9]	Pungent, benzene-like odor. CHID under development.
Toluene 2,4-diisocyanate 584-84-9	0.14 [0.02]	0.59 [0.083]	3.6 [0.51]	0.07 [0.01]	0.036 [0.005]	Irritation eyes, skin, nose, throat; choke, paroxysmal cough; chest pain; vomiting, abdominal pain; bronchospasm, pulmonary edema; difficulty breathing, asthma; conjunctivitis, excessive tearing; dermatitis, skin sensitization.	Eyes, skin, RS	NA	Known sensitizer. Subsequent exposures may lower effect concentration. Potential occupational carcinogen; strong, pungent odor.

Chemical CAS No.	1-Hour Air-MEG mg/m^3 [ppm] Health Effect Level Minimal	Significant	Severe	8-Hour Air-MEG mg/m^3 [ppm]	14 Day Air-MEG mg/m^3 [ppm]	Potential Symptoms [?N]	Target Organs [N] and Systems	Odor[?] Threshold mg/m^3 [ppm]	Notes
Trichloroethylene 79-01-6	537 [100]	2687 [500]	26,870 [5000]	270 [50]	6.6 [1.2]	Headache, fatigue, and irritability.	CNS	[28]	
Trichloropropane (1,2,3-) 96-18-4	181 [30]	302 [50]	603 [100]	60[S] [10]	1.5[S] [0.24]	Irritation eyes, nose, throat; CNS depressant/depression; in animals: liver, kidney injury.	Eyes, skin, RS, CNS, liver, kidneys	NA	Dermal exposure may contribute to total dose; potential occupational carcinogen.
Tungsten hexafluoride 7783-82-6	ND	ND	ND	1 [0.125]	0.024 [0.003]	Nausea, vomiting, abdominal pain, convulsions, and kidney damage; irritation of the eyes, nose, throat, and skin.	Kidney, CNS, eyes, skin, URS	NA	These acute symptoms were based on exposure to high levels of fluorides; no known health effects from exposure to tungsten hexafluoride[NJ]; 1-14 day value based on soluble tungsten.
VX 50782-69-9	See Table C-1								
Xylene (mixed) 1330-20-7	650 [150]	868 [200]	3906 [900]	435 [100]	10.6 [2.4]	Lightheadedness, nausea, headache, and ataxia at low doses and confusion; respiratory depression and coma at high doses; above 200 ppm, conjunctivitis, nasal irritation, and sore throat; it is a potent respiratory irritant at high concentrations; dermatitis with prolonged cutaneous	CNS, eyes, skin, RS[H]	[0.081 40]	Sweet, aromatic odor.

Chemical CAS No.	1-Hour Air-MEG mg/m^3 [ppm]			8-Hour Air-MEG mg/m^3 [ppm]	14 Day Air-MEG mg/m^3 [ppm]	Potential Symptoms [N]	Target Organs [N] and Systems	Odor [?] Threshold mg/m^3 [ppm]	Notes
	Health Effect Level								
	Minimal	Significant	Severe						
						exposure.[H]			

FOOTNOTES FOR TABLE C-2 – SHORT-TERM AIR MEGS

c – Ceiling value (ACGIH, 1998).
s – Skin notation; dermal exposures have the potential for significant contribution to overall dose.
† - Compounds classified per ACE Policy for Defensive Measures against Toxic Industrial Chemical Hazards during Military Operations (NATO/PFP, 1996).

CHID – Chemical Hazard Information for Deployments. Additional Fact Sheet information is under development for notated Chemicals.
EKG - electrocardiogram
H – Hazardous Substances Data Base.
I – Acute Exposure Symptoms which may occur at exposures above MEGs-S.
M – National Research Council, Committee on Toxicology. 1997. *Toxicity of Military Smokes and Obscurants*, National Academy Press, Washington, DC
N – National Institute of Safety and Occupational Health (NIOSH) Pocket Guide (unless otherwise noted).
NA – Not Available; data insufficient to derive a value.
ND – Not Determined; data not yet reviewed to derive a value.
NJ – New Jersey Substance Fact Sheet.
NOAEL – No Observable Adverse Effect Level
R – Chemical Hazard Response Information System.
RTECS – Registry of Toxic Effects of Chemical Substances.
T – Compton, James A. F. 1987. *Military Chemical and Biological Agents*, The Telford Press, Caldwell, NJ.

The primary sources of odor thresholds in air were the *Odor Thresholds for Chemicals with Established Occupational Health Standards*, published by the American Industrial Hygiene Association, Akron, OH, 1989, and the N. J. Hazardous Substances Fact Sheets.

TABLE 2-4-1. TARGET ORGANS

TARGET ORGANS	
Eyes	Brain
Skin	Heart
Blood	Pancreas
Bladder	Adrenal Glands
Thyroid	Lungs
Bone	Liver
Fetus	Kidneys
Spleen	

TABLE 2-4-2. TARGET SYSTEMS

TARGET SYSTEMS	
CNS – Central Nervous System	CVS – Cardiovascular System
PNS – Peripheral Nervous System	ChE Inh – Cholinesterase Inhibitor
GI tract – Gastrointestinal Tract	UT – Urogenital Tract
RS – Respiratory System	CRC – Circulatory System
LRS – Lower Respiratory System	IMM – Immune System
URS – Upper Respiratory System	REPR – Reproductive System
ENDO – Endocrine System	HEM – Hemopoietic System
LYMP – Lymphatic System	

TABLE C-3. LONG-TERM, AIR MILITARY EXPOSURE GUIDELINES (1 YEAR DEPLOYMENT)

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
Acenaphthene 83-32-9	0.14 [0.023]	NA	Skin and eye irritation, coughing and wheezing.	Skin, eyes, RS, kidney, liver	0.50 [0.08]	
Acenaphthylene 208-96-8	0.028 [0.0045]	D	ND	ND	NA	Little data is available on this compound. Effects may be comparable to other PAHs.
Acetaldehyde 75-07-0	0.0062 [0.0034]	B2	Irritation of the eyes, nose, throat; eye, skin burns; dermatitis; conjunctivitis; cough; CNS depression; delayed pulmonary edema; kidney, reproductive, teratogenic effects; cancer.	RS, eyes, skin, kidneys, CNS, REPR	0.0002-4.14 Green, sweet, fruity odor	Air unit risk based on increased incidence of nasal tumors in rats and laryngeal tumors in hamsters after inhalation exposure.
Acetone 67-64-1	29.0 [12.2]	D	Eye, nose and throat irritation, headache, dizziness, CNS depression, dermatitis.	Eyes, skin, RS, CNS	30.9 [13] Fruity odor	High vapor concentrations produce anesthetic effects.
Acetone cyanohydrin 75-86-5	0.068 [0.020]	NA	Irritation of the eyes, skin, respiratory system; dizziness, weakness, headache, confusion, convulsions; liver, kidney injury; pulmonary edema, asphyxia.	CNS, eyes, skin, RS, CVS, liver, kidneys, GI tract	Cyanide, bitter almond odor	Skin – dermal exposures have the potential for significant contribution to overall dose[Ac].

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
Acetonitrile 75-05-8	0.34 [0.20]	D	Irritation of nose, throat; asphyxiation, nausea, vomiting; chest pain; weakness; stupor, convulsions; liver, kidney damage.	Liver, kidneys, RS, CVS, CNS	70 Ether-like odor	
Acrolein 107-02-8	0.000014 [0.0000060]	C	Irritation eyes, skin, mucous membranes; decreased pulmonary function; delayed pulmonary edema; chronic respiratory disease; cancer.	Eyes, skin, RS, heart	0.0525-37 Burnt sweet odor	Skin – dermal exposures have the potential for significant contribution to overall dose[Ac].
Acrylamide 79-06-1	0.0037 [0.0013]	B2	Irritation of eyes, skin ataxia, numb limbs, abnormal sensations; muscular weakness; absent deep tendon reflex; fatigue, reproductive effects (mammary gland, uterus, testes), cancer, lethality	CNS, PNS, REPR, ENDO, RS, GI tract, eyes, skin	NA	C Skin – dermal exposures have the potential for significant contribution to overall dose[Ac].
Acrylic acid 79-10-7	0.14 [0.048]	NA	Irritation of eyes, skin, respiratory system; eye, skin burns, skin sensitization; reproductive effects; lung, liver, kidney.	Liver, kidneys, eyes, skin, RS, REPR	0.282-3.12 Rancid, sweet odor	Skin – dermal exposures has the potential or significant contribution to overall dose[Ac].
Acrylonitrile 107-13-1	0.11 [0.049]	B1	Irritation eyes, skin; asphyxia; headache; sneezing; nausea, vomiting; weakness, lightheadedness; skin vesiculation; scaling dermatitis; brain tumors; lung and bowel cancer.	RS, eyes, skin, CVS, liver, kidneys, CNS	8.1-78.75 Onion-garlic pungency	Skin – dermal exposure have the potential for significant contribution to overall dose[Ac]. Air unit risk based on respiratory cancer in humans from occupational inhalation exposure.

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
Aldrin 309-00-2	0.00098 [0.000066]	B2	Headache, dizziness; nausea, vomiting, malaise; myoclonic jerks of limbs; clonic, tonic convulsions; coma; hematuria, azotemia, thyroid and adrenal effects, cancer.	CNS, liver, kidneys, skin, LRS, ENDO	0.2536-0.4027	C Skin – dermal exposures have the potential for significant contribution to overall dose[Ac].
Allyl chloride 107-05-1	0.077 [0.025]	C	Irritation eyes, skin, nose, mucous membranes; pulmonary edema, liver, kidney injury; cancer.	CNS, eyes, skin, RS, liver, kidneys	1.41-75 Green garlic, oniony odor	Dermal exposures may contribute to overall dose.
Ammonia 7664-41-7	0.35 [0.5]	NA	Irritation eyes, nose, throat; dyspnea, bronchospasm; pulmonary edema; pink frothy sputum; skin burns; cancer.	RS, eyes, skin	0.0266-39.6 Pungent, irritating odor	
Aniline 62-52-3	0.19 [0.049]	B2	Headache, weakness, dizziness; cyanosis; dyspnea on effort; tachycardia; irritation of eyes; methemoglobinuria, cirrhosis; tumors of the spleen; cancer.	Blood, CVS, eyes, liver, kidneys, LRS	0.0002-350 Pungent, amine-like odor	Skin – dermal exposures have the potential for significant contribution to overall dose[Ac].
Antimony trioxide 1309-64-4	0.00014 [0.000020]	NA	Irritation eyes, respiratory system, antimony pneumoconiosis.	RS, liver[I]	NA	
Anthracene 120-12-7	35 [4.2]	D	Skin, nose, throat, and eye irritation, itching, burning, coughing, and wheezing, photosensitizer.	Skin, eyes, RS	Weak aromatic odor	Photosensitizing of this agent can increase dermal effects.

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
Arsenic 7440-38-2	0.0011 [0.00036]	A	Ulceration of nasal septum; dermatitis; GI disturbances; peripheral neuropathy; respiratory irritation; hyperpigmentation of skin; lung and lymphatic cancer.	RS, skin, CVS, liver, kidneys	NA	C CHID under development.
Arsine 7784-42-1	0.000034 [0.000011]	NA	Headache, malaise; dyspnea; nausea, vomiting; bronze skin; hemolysis; jaundice; peripheral neuropathy.	Blood, liver, kidneys, lungs, CVS	0.84-2 Garlic-like odor	
Azobenzene 103-33-3	0.15 [0.021]	B2	Azobenzene induced invasive sarcomas in the spleen and other abdominal organs in male and female F344 rats following dietary administration. It is genotoxic and may be converted to benzidine, a known human carcinogen, under the acidic conditions in the stomach[I]; cancer.	GI tract	NA	C
Barium 7440-39-3	0.0034 [0.00061]	NA	Irritation to eyes, upper respiratory system, acute lung and gastrointestinal effects; baritosis.	Eyes, skin , RS, GI tract, fetus	NA	

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
Benzene 71-43-2	0.039 [0.012]	A	Irritation of eyes, skin, nose, respiratory system; giddiness; headache, nausea, staggered gait; fatigue, anorexia, lassitude (weakness, exhaustion); dermatitis; bone marrow depression, leukemia; cancer.	HEM, eyes, skin, RS, blood, CNS	4.5-270 Sweet, solvent odor	Skin – dermal exposures have the potential for significant contribution to overall dose[Ac]. Air unit risk based on leukemia in humans exposed by inhalation. Chronic exposures to low concentrations causes bone marrow depression. CHID under development.
Benzidine 92-87-5	0.000072 [0.0000095]	A	Hematuria; secondary anemia from hemolysis; acute cystitis; acute liver disorders; dermatitis; painful irregular urination; cancer.	Bladder, skin, kidneys, liver, blood	NA	C Skin – dermal exposures have the potential for significant contribution to overall dose[Ac].
Benzo(a)anthracene 56-55-3	0.054 [0.0058]	B2	Benzo(a)anthracene produced tumors in mice exposed by gavage; intraperitoneal, subcutaneous or intramuscular injection; and topical application[I]; cancer.	RS, liver, GI tract [I]	NA	C

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
Benzo(a)pyrene 50-32-8	0.0054 [0.00053]	B2	Repeated Benzo(a)pyrene administration has been associated with increased incidences of total tumors and of tumors at the site of exposure in dietary, gavage, inhalation, intratracheal instillation, dermal and subcutaneous studies in numerous strains of at least four species of rodents and several primates[I]; cancer.	GI tract, RS, skin[I]	Faint aromatic odor	
Benzo(b)fluoranthene 205-99-2	0.054 [0.0053]	B2	Benzo(b)fluoranthene produced tumors in mice after lung implantation, intraperitoneal or subcutaneous injection, and skin painting[I]; cancer.	RS, liver, skin[I]	NA	C
Benzo(k)fluoranthene 207-08-0	0.54 [0.053]	B2	Benzo(k)fluoranthene produced tumors after lung implantation in mice and when administered with a promoting agent in skin-painting studies[I]; cancer.	RS, skin, liver[I]	NA	C
Beryllium 7440-41-7	0.000014 [0.000037]	B1	Sensitization, irritation of eyes; dermatitis; cumulative lung damage berylliosis - chronic exposure: anorexia, low weight, weakness, chest pain, cough, clubbing of fingers, cyanosis, pulmonary insufficiency; lung cancer [I,N].	Eyes, skin, RS, CNS[I,N]	NA	Air unit risk based on lung cancer in humans from occupational inhalation exposures.

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
Bis (2-ethylhexyl) phthalate 117-81-7	0.12 [.00767]	B2	Eye irritation, liver damage, possible teratogenic and carcinogenic effects.	Eyes, skin, RS., CNS, liver, REPR, GI tract	Odorless	C Slope factor based on dose-response increase of liver tumors in rats.
Bis-2-Chloro-1-methylethyl ether 108-60-1	0.0014 [0.0002]	C	Cancer	Liver[H]	NA	C
Bis-2-Chloroethyl ether 111-44-4	0.015 [0.0025]	B2	Cancer	Liver[H]	[0.049] Pungent, sweet, chloroform-like odor	C
Boron 7440-42-8	0.014 [0.031]	NA	Respiratory irritation, bronchitis[H].	RS[H]	NA	
Boron trifluoride 7637-07-2	0.0048 [0.0017]	NA	Irritation eyes, skin, nose, respiratory system; epistaxis (nosebleed); pneumo nia; kidney damage.	Eyes, skin, RS, kidneys	4.5 Pungent, irritating	
Bromoethylene 593-60-2	0.0021 [0.00047]	B2	Irritation eyes, skin; dizziness, confusion, incoordination, narcosis, nausea, vomiting[N]; liver injury and cancer[H].	Eyes, skin, CNS, liver, GI tract[N]	Characteristic pungent odor	Bromoethene appeared carcinogenic (in liver) in this study at higher doses.

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
Bromoform 75-25-2	0.13 [0.012]	B2	Irritation of eyes, skin, respiratory system, CNS depression, liver, kidney damage, cancer of the GI tract.	GI tract, eyes, skin, RS, liver, kidneys	5300 Odor similar to chloroform	C Skin – dermal exposures have the potential for significant contribution to overall dose[Ac].
Butadiene (1,3-) 106-99-0	0.017 [0.0077]	B2	Irritation of the eyes, nose and throat; drowsiness, light-headedness; teratogenic, reproductive effects; cancer.	Eyes, RS, REPR, heart, HEM, CVS	0.352-2.86	C
sec-Butylbenzene 135-98-8	0.025 [0.00462]	NA	Irritation of eyes, nose, throat, and skin, CNS depression, incoordination, nausea, general anesthetic effects.	Eyes, RS, skin	NA	
Cadmium (elemental) 7440-43-9	0.00024 [0.000053]	B1	Pulmonary edema, dyspnea, cough, tight chest, substernal pain, headache, chills, muscular aches, nausea, vomiting, diarrhea, emphysema, proteinuria, anosmia (loss of sense of smell), mild anemia, cancer.	RS, kidneys, REPR, blood, GI tract	NA	C
Cadmium (compounds)	0.000049	NA	Cancer; kidney effects; metal fume fever tumors of lung, trachea, bronchus (cancer deaths) in human occupational epidemiology study.	RS, kidneys	NA	

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
Carbon disulfide 75-15-0	0.48 [0.15]	NA	Dizziness, headache, nervousness, anorexia, polyneuropathy, psychosis, Parkinson-like syndrome, ocular changes, coronary heart disease, gastritis, kidney, liver injury, dermatitis, reproductive effects.	PNS, CNS, CVS, eyes, kidneys, liver, skin, REPR	0.0243-23.1 Disagreeable sweet odor	Skin – dermal exposures have the potential for significant contribution to overall dose[Ac].
Carbon monoxide 630-08-0	3.3 [3]		Headache, tachypnea, nausea, weakness, dizziness, confusion, hallucinations, cyanosis, electrocardiogram alterations, angina, syncope	CNS, CVS, fetus	NA	See Section 4.4.1 for additional information.
Carbon tetrachloride 56-23-5	0.32 [0.051]	B2	Irritation eyes, skin; CNS depression; nausea, vomiting; liver, kidney injury; drowsiness, dizziness, incoordination, cancer.	Eyes, skin, liver, CNS, RS, kidneys	300-1500 Sweet, pungent odor	C Skin – dermal exposures have the potential for significant contribution to overall dose[Ac].
Chlordane 57-75-9	0.00048 [0.000029]	B2	Blurred vision; confusion, ataxia, delirium; cough; abdominal pain, nausea, vomiting, diarrhea; irritability, tremor, convulsions; anuria; lung, liver and kidney damage; cancer.	Liver, ENDO, IMM, CNS, eyes, kidneys	0.0084-0.0419	Skin – dermal exposures have the potential for significant contribution to overall dose[AC]. Compound is lipid soluble and expected to bioaccumulate. Air unit risk calculated based on hepatocellular carcinoma in mouse drinking water study.

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
Chlorine dioxide 10049-04-4	0.0068 [0.0025]	NA	Irritation of eyes, nose, throat; cough, wheezing, bronchitis, pulmonary edema; chronic bronchitis.	RS, eyes	0.3 Sharp, pungent odor	
Chloroacetophenone (2-) (CN) 532-27-4	0.00021 [0.000032]	NA	Lacrimation, irritation of the skin, rashes in tender skin areas of the armpits, knees, elbows, areas of the crotch and buttocks[T].	RS, skin, eyes[T]	0.102-0.15 Sharp and irritating odor	
Chlorobenzilate 510-15-6	0.0612 [0.0046]	B2	Cancer	Liver[H]	NA	C Skin – dermal exposures have the potential for significant contribution to overall dose[Ac].
Chloro-1,3-butadiene (2-) 126-99-8	0.048 [0.013]	NA	Upper respiratory system effects.	URS, CNS, blood, liver[Ac]	NA	Skin – dermal exposures have the potential for significant contribution to overall dose[Ac].
Chloro-1,1-difluoroethane (1-) 75-68-3	34.2 [8.3]	NA	None identified up to a human equivalent concentration of 14,710 mg/m3[I]	CNS, CVS, LRS, fetus	NA	Effects at very high doses: A LOAEL was not achieved.
Chlorodifluoromethane 75-45-6	3.42 [9.7]	NA	Irritation respiratory system; confusion, drowsiness, ringing in ears; heart palpitations, cardiac arrhythmias; asphyxiation; liver, kidney, spleen injury.	Kidneys, ENDO, RS, CVS, CNS, liver	NA	

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
Chloroethane 75-00-3	6.8 [2.6]	NA	Effects on fetus.	Fetus, CNS, CVS	[4.2] Pungent, ether-like odor	
Chloroform 67-66-3	0.21 [0.043]	B2	Irritation eyes, skin; dizziness, mental dullness, nausea, confusion, headache, fatigue; anesthesia; enlarged liver; cancer.	Kidneys, liver, heart, eyes, skin, CNS	250-1000 Pleasant, ether-like odor	C
Chloromethane 74-87-3	2.7 [1.3]	C	Tumors[H]; cancer.	Kidneys[H]	[10] Faint, sweet odor	
Chloropropane (2-) 75-29-6	0.68 [0.21]	NA	Liver effects	Liver[H]	NA	
Chromium Metal and Cr III compounds 7440-47/16065-83-1	0.012	NA	Irritation; dermatitis.	Eyes, skin, RS	NA	
Chromium (VI) (water soluble) CrVI 18540-29-9	0.00068	NA	Nasal irritation and atrophy; decreased pulmonary function; liver, kidney effects; cancer.	RS; liver; kidneys	NA	

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
Chromium (VI) (insoluble) CrVI 18540-29-9	0.000068	A	Irritation to eyes; dermal sensitization; lung, liver, kidney effects, cancer[N,I].	Skin, eyes, LRS, liver, kidneys, blood, IMM[N,I]	NA	Air unit risk based on lung cancer in humans from occupational inhalation exposure. Trivalent chromium compounds have not been reported as carcinogenic by any route of administration[I].
Chrysene 218-01-9	5.5 [0.58]	B2	Chrysene produced carcinomas and malignant lymphomas in mice after intraperitoneal injection and skin carcinomas in mice following dermal exposure[I]; cancer.	Liver, LRS, skin [I]	NA	C Skin – dermal exposures have the potential for significant contribution to overall dose[Ac].
Cumene 98-82-8	2.74 [0.6]	D	Irritation to eyes, skin, mucous membranes; dermatitis; headache, narcosis, coma.	CNS, URS, eyes, skin	0.04-6.4 Sharp, aromatic odor	
Cyclopentadiene 542-92-7	2.1 [0.76]	NA	Irritation of eyes, nose; liver, kidney effects.	Liver, kidneys, eyes, URS	5.07 Turpentine-like odor	

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
P,p'-DDT 50-29-3	0.049 [0.0034]	B2	Irritation eyes, skin; paresthesia tongue, lips, face; tremor; apprehension, dizziness, confusion, malaise, headache, fatigue; convulsions; paresis hands; vomiting, cancer.	Liver, eyes, skin, CNS, PNS, kidneys, LRS, LYM	5.07 Slight aromatic odor	
Dibenzo(a,h)anthracene 53-70-3	0.0054 [0.00048]	B2	Bibenzo(a,h)anthracene produced carcinomas in mice following oral or dermal exposure and injection site tumors in several species following subcutaneous or intramuscular; cancer.	Skin, RS, REPR [I]	NA	C
Dibromo -3-chloropropane (1,2-) 96-12-8	0.00014 [0.000014]	B2	Irritation eyes, skin, nose, throat; drowsiness; nausea; vomiting; pulmonary edema; liver, kidney effects, cancer.	RS, eyes, skin, liver, kidneys, blood, REPR	0.1-0.29 Pungent odor	Slope factor based on tumors of the nasal cavity in rat and mouse inhalation studies.
Dichlorobenzene (1,2-) 95-50-1	1.4 [0.23]	D	Irritation eyes, nose; liver, kidney damage, skin blisters.	Eyes, skin, URS, liver, kidneys	12-300 Pleasant, aromatic odor	
Dichlorobenzene (1,4-) 106-46-7	1.7 [0.28]	B2	Eye irritation, periorbital swelling; profuse rhinitis; headaches, anorexia, nausea, vomiting; low weight, jaundice, cirrhosis; liver and kidney cancer.	Liver, URS, eyes, kidneys	90-180 Mothball odor	

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
Dichloro-2-butene (1,4-) 764-41-0	0.0018 [0.00036]	B2	Cancer	URS[H]	Sweet, pungent odor	C Skin – dermal exposures have the potential for significant contribution to overall dose[Ac].
Dichlorodifluoromethane 75-71-8	99.0 [24.4]	NA	Dizziness, tremor, asphyxiation, unconsciousness, cardiac arrhythmias, cardiac arrest, liver effects.	Liver, CVS, PNS	NA	
Dichloroethane (1,1-) 75-34-3	3.42 0.85	C	Irritation skin; CNS depression, liver, kidney, lung damage; cancer.	Kidneys, skin, liver, LRS, CNS	445.5-810 Chloroform-like odor	
Dichloroethane (1,2-) 107-06-2	0.18 [0.045]	B2	Liver effects, narcosis[Ac]; cancer.	Liver, CNS	24-440 Sweet odor	C
Dichloroethylene (1,1-) 75-35-4	0.096 [0.024]	C	Cancer	Kidneys, liver, CNS	2000-4000 Sweet, chloroformish odor	C
Dichloropropane (1,2-) 78-87-5	0.022 [0.0048]	NA	Nasal mucosa hyperplasia, CNS, liver, kidney effects.	URS, CNS, liver, kidneys[Ac]	1.1667-606.666 Sweet odor	

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
Dichloropropene (1,3-) 542-75-6	0.014 [0.0030]	B2	Irritation eyes, skin, respiratory system; eyes, skin burns; lacrimation; headache, dizziness; liver, kidney damage; cancer.	URS, CNS, liver, kidneys[Ac]	Sharp, sweet, chloroform-like odor	Skin – dermal exposures have the potential for significant contribution to overall dose[Ac]. Slope factor based on findings of lung adenoma in 2-year mouse inhalation study.
Dichlorvos 62-73-7	0.0018 [0.0002]	B2	Irritation eyes, skin; miosis, aching eyes, rhinitis; headaches; chest tight, wheezing, laryngeal spasms, salavation; cyanosis; anorexia, nausea, vomiting, diarrhea sweating; muscle fasciculations, paralysis, giddiness, ataxia, convulsions, low blood pressure, cardiac irregularities; cancer.	Eyes, skin, ChE Inh, CNS, RS, CVS	Mild, aromatic odor	Skin – dermal exposures have the potential for significant contribution to overall dose[Ac].
Dicyclopentadiene 77-73-6	0.014 [0.0025]	NA	Irritation eyes, skin, nose, throat; incoordination, headaches; sneezing, cough; skin blisters; kidney, lung damage.	Eyes, skin, kidneys, RS, CNS, eyes, skin	0.03-0.054 Sharp, sweet odor	
Dieldrin 60-57-1	0.0010 0.000067	B2	Headache, dizziness; nausea, vomiting, malaise, sweating; myoclonic limb jerks; clonic, tonic convulsions; coma; liver, kidney damage, cancer.	Liver, CNS, kidneys, skin, RS, ENDO	[0.04] Mild, chemical odor	C Skin – dermal exposures have the potential for significant contribution to overall dose.[Ac].

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
Diesel engine emissions	0.0034	NA	Eye irritation; pulmonary function changes; lung inflammation; lung tumors.	Eyes, URS	NA	Measured by diesel particulate matter.
Difluoroethane (1,1-) 75-37-6	27.4 [10.0]	NA	Nasal olfactory epithelium atrophy at high doses; CNS depression at extremely high doses.	URS; CNS	NA	A LOAEL was not determined.
Dimethylformamide (N,N-) 68-12-2	0.062 [0.021]	NA	Irritation eyes, skin, respiratory system; nausea, vomiting, colic; liver damage, enlarged liver; high blood pressure; face flushing; dermatitis; kidney, heart damage.	Liver, GI tract, RS, eyes, skin, kidneys, CVS	300 Faint amine-like odor	Skin – dermal exposures have the potential for significant contribution to overall dose[Ac].
Diphenylhydrazine (1,2-) 122-66-7	0.022 [0.0029]	B2	Cancer	Liver[I]	NA	C
Epichlorohydrin 106-89-8	0.0068 [0.0018]	B2	Irritation eyes, skin with deep pain; nausea, vomiting; abdominal pain; respiratory distress, cough; cyanosis reproductive effects; cancer.	RS, eyes, skin, kidneys, liver, REPR	50-80 Chloroform-like odor	Skin – dermal exposures have the potential for significant contribution to overall dose[Ac]. Slope factor based on tumors of the nasal cavity in rat inhalation study.

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
Epoxybutane (1,2-) 106-88-7	0.014 [0.0046]	NA	Irritation nose, respiratory system; effects on blood.	Respiratory system, blood[I]	Disagreeable odor	
Ethoxyethanol (2-) 110-80-5	1.4 [0.37]	NA	Irritation eyes, respiratory system; blood changes; liver, kidney, lung damage; reproductive, teratogenic effects.	Blood, eyes, kidneys, liver, HEM, REPR, RS	[2.7] Mild, agreeable, ether-like odor	Skin – dermal exposures have the potential for significant contribution to overall dose[Ac].
Ethyl benzene 100-41-4	2.95 [0.68]	D	Irritation eyes, skin, mucous membrane; headache; dermatitis; narcosis, coma.	Fetus, liver, kidneys, blood, eyes, skin, RS, CNS	8.7-870 Aromatic odor	
Ethyl chloride 75-00-3	6.8 [2.6]	NA	Incoordination, inebriation; abdominal cramps; cardiac arrhythmias, cardiac arrest; liver, kidney damage.	Fetus, liver, kidneys, RS, CNS	[4.2] Pungent, ether-like	Skin – dermal exposure have the potential for significant contribution to overall dose[Ac].
Ethylene dibromide 106-93-4	0.0014 [0.00018]	B2	Reproductive effects, cancer.	REPR	[8.1-10] Sweet odor	Slope factor was based on tumors of the nasal cavity in 88 to 103-week rat inhalation study.
Ethylene glycol monobutyl ether 111-76-2	0.14 [0.028]	NA	Altered hematology.	Blood[H]	[0.1] Mild, ether-like odor	

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
Ethylene oxide 75-21-8	0.048 [0.027]	B1	Irritation eyes, skin, nose, throat; peculiar taste; headache, nausea; vomiting, diarrhea; dyspnea, cyanosis, pulmonary edema; incoordination; EKG abnormalities; convulsions, liver, kidney damage in animals; cancer.	Eyes, skin, RS, liver, CNS, blood, kidneys, REPR	520-1400 Sweet olefininic odor	C
Fluoranthene 206-44-0	1.4 [0.17]	D	ND	ND	NA	Little toxicity data is available for this compound.
Fluorene 86-73-7	1.4 [0.17]	D	Irritation of skin and eyes.	Skin, eyes.	NA	Little toxicity data is available for this compound.
Formaldehyde 50-00-0	0.25 [0.20]	B1	Irritation eyes, nose, throat, respiratory system; lacrimation; cough, bronchospasm; cancer.	RS, eyes	1.47-73.5 Pungent, hay odor	C Minor irritation of the nose and throat and skin sensitization may occur at this level.
Furfural 98-01-1	0.34 [0.087]	NA	Irritation eyes, skin, upper respiratory tract; headache; dermatitis.	RS, eyes, skin	0.024-20 Almond odor	Skin – dermal exposures have the potential for significant contribution to overall dose[AC].

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
Glycidaldehyde 765-34-4	0.0068 [0.0023]	B2	Body weight changes, kidney effects.	Kidneys[H]	Pungent, aldehyde-like odor	
Heptachlor 76-44-8	0.0037 [0.00024]	B2	Tremor, convulsions; liver damage, cancer.	Liver, CNS	0.306 Camphor-like odor	C Skin – dermal exposures have the potential for significant contribution to overall dose[Ac].
Heptachlor epoxide 1024-57-3	0.0018 [0.00012]	B2	Cancer	Liver[I]	NA	C
Hexachlorobenzene 118-74-1	0.000049 [0.0000052]	B2	Liver effects; metabolic disorders (e.g. thyroid disorders), cancer[Ac,I]	Liver, ENDO, kidneys[I]	NA	C Skin – dermal exposures have the potential for significant contribution to overall dose[Ac].
Hexachlorobutadiene 87-68-3	0.0052 0.00049	C	Irritation, eyes, skin, respiratory system; kidney damage; liver cancer in animals.	Eyes, skin, RS, kidneys	12 Turpentine-like odor	Skin – dermal exposures have the potential for significant contribution to overall dose[Ac].
Alpha-Hexachlorocyclohexane (HCH) 319-84-6	0.0027 [0.00022]	B2	Cancer	Liver[I]	NA	C

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
Beta Hexachlorocyclohexane (HCH) 319-85-7	0.0090 [0.00076]	C	Cancer	Liver[J]	NA	C
Technical Hexachlorocyclohexane (HCH) 608-73-1	0.00094 [0.00079]	B2	Cancer	Liver[J]	NA	C
Hexachlorocyclopentadiene 77-47-4	0.076 [0.0068]	D	Irritating to eyes, skin, respiratory system; lacrimation; sneezing, cough, dyspnea, salivation, pulmonary edema; nausea, vomiting, diarrhea; liver, kidney injury in animals.	RS, eyes, skin, liver, kidneys	1.5-3.3 Pungent, unpleasant odor	Effects are concentration rather than time dependent.
Hexachlorodibenzodioxin mix 19408-74-3	0.0000037	B2	Cancer	Liver[J]	NA	C

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
Hexachloroethane 67-72-1	1.20 [0.12]	C	Irritating to eyes, skin, mucous membranes; kidney; liver; CNS, cancer.	Eyes, skin, RS, liver, kidneys, CNS	[0.15] Camphor-like odor	C Skin – dermal exposures have the potential for significant contribution to overall dose[AC]. The MEG for hexachloroethane does not refer to HC Smoke. The toxicity of HC Smoke is based on the production of $ZnCl_2$ and respiratory effects and alvelogenic carcinoma. The PEGL for $ZnCl_2$ is 0.2 mg/m^3.
Hexamethylene diisocyanate (1,6-) 822-06-0	0.00014 [0.00002]	NA	Irritation eyes, skin, mucous membranes, respiratory system; cough, dyspnea, bronchitis, wheezing, pulmonary edema, asthma.	RS, eyes, skin	Sharp, pungent odor	
Hexane (other isomers)	43 [12.2]	NA	Irritation eyes, nose, throat; CNS effects (peripheral neuropathy for hexane)	CNS; eyes, URS	NA	
Hexane (n-) 110-54-3	4.3 [1.2]	NA	Irritation eyes, nose; light-headedness; nausea, headache; peripheral neuropathy: numbness extremities, muscle weakness; dermatitis; giddiness.	CNS, eyes, skin, URS, PNS	[130] Gasoline-like odor	Skin – dermal exposure have the potential for significant contribution to overall dose[Ac].

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
Hydrazine 302-01-2	0.00098 [0.00075]	B2	Irritation eyes, skin, nose, throat; temporary blindness; dizziness, nausea; dermatitis; eyes, skin burns; bronchitis, pulmonary edema; liver, kidney damage, convulsions; cancer.	RS, eyes, skin, CNS, liver, kidneys	3-4 Ammonical, fishy odor	C Skin – dermal exposures have the potential for significant contribution to overall dose[AC].
Hydrogen chloride 7647-01-0	0.014 [0.0092]	NA	Irritation nose, throat, larynx; cough, choking; dermatitis; larygeal spasm; pulmonary edema.	RS, eyes, skin	[0.77] Pungent, irritating odor	Asthmatics may experience adverse effects above 3 ppm (4.47 mg/m^3).
Hydrogen cyanide 74-90-8	0.0021 [0.0019]	NA	Asphyxia, weakness, headache, confusion; nausea, vomiting; increased rate and depth of respiration or respiration slow and gasping; thyroid, blood changes.	CNS, CVS, ENDO, blood	0.9-5 Bitter, almond, slightly sharp odor	Skin – dermal exposures have the potential for significant contribution to overall dose[Ac].
Hydrogen sulfide 7783-06-4	0.15 [0.11]	NA	Irritation eyes, respiratory system; apnea; conjunctivitis, eye pain, lacrimation photophobia (abnormal visual intolerance to light), corneal vesiculation; dizziness, headache, fatigue, insomnia, convulsions, coma; GI disturbances.	URS, eyes, CNS	0.0007-0.014	Rotten egg odor below 0.03 mg/m^3; higher, toxic concentrations rapidly deaden sense of smell.
Indeno(1,2,3-c,d)pyrene 193-39-5	0.054 [0.0048]	B2	Indeno(1,2,3-c,d)pyrene produced tumors in mice following lung implants, subcutaneous injection and dermal exposure; cancer.	RS, skin [I]	NA	C; skin exposure site cancers

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
Lead 7439-92-1	0.0015	NA	Weakness, lassitude, insomnia, facial pallor; anorexia, constipation, abdominal pain; anemia; tremor, paralysis wrist/ankles; kidney disease; irritation eyes; hypo/hyper tension.	CNS, PNS, blood, CVS, kidneys, REPR, fetus, GI tract, eyes	NA	See section 4.4.1 for more information. CHID under development.
Manganese 7439-96-5	0.00034 [0.00015]	D	Dry throat, cough, chest, tightness, dyspnea, rales, flu-like fever, low-back pain; vomiting; malaise; fatigue; kidney damage; Parkinson's asthenia (weakness), insomnia, mental confusions; metal fumes fever.	CNS, RS, blood, kidneys	NA	Neurobehavioral effects are a concern at moderate levels.
Mercury (inorganic) 7439-97-6	0.00021 [0.000025]	D	Irritating to eyes, skin; cough, chest pain, dyspnea, bronchitis, pneumonitis; tremor, insomnia, irritability, indecision, headache, fatigue, weakness; stomatitis, salivation, GI distress, anorexia, low-weight, proteinuria.	Eyes, skin, CNS, RS, kidneys	NA	Skin – dermal exposures have the potential for significant contribution to overall dose[Ac].
Methoxyethanol (2-) 109-86-4	0.14 [0.044]	NA	Reproductive effects (testes).	REPR, CNS, blood	[2.3] Mild, ether-like	Skin – dermal exposures have the potential for significant contribution to overall dose[Ac].

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
Methylacrylonitrile 126-98-7	0.067 [0.025]	NA	Irritation eyes, skin; lacrimation; CNS effects, convulsions, loss of motor control; liver.	Liver, CNS, eyes, skin	6-42 Bitter almond odor	
Methyl Bromide 74-83-9	0.09 [0.024]	NA	Lesions of the nasal cavity.	URS, heart, GI tract, CNS, blood[I]	NA	Neurological effects may not be reversible.
Methylcyclohexane 108-87-2	39.3 [9.79]	NA	Irritating to eyes, skin, nose, throat; light-headedness, drowsiness, narcosis, kidneys.	Kidneys, eyes, skin, URS, CNS	2000 Faint, benzene-like odor	
Methylenebis-2-chloroaniline (4,4-) 101-14-4	0.0027 [0.00024]	B2	Hematuria, cyanosis, nausea, methemoglobinemia, kidney irritation, cancer.	LRS, liver, blood, kidneys	NA	C Skin – dermal exposures have the potential for significant contribution to overall dose[Ac].
Methylene chloride 75-09-2	2.1 [0.59]	B2	Irritating to eyes, skin; fatigue, weakness, somnolence, light-headedness; numb tingling limbs; nausea, cancer.	Liver, eyes, skin, CNS, CVS, LRS, REPR, GI tract	540-2160 Sweet odor	Slope factor based on combined adenomas and carcinomas in 2-year mouse inhalation studies.
Methylenediphenyl isocyanate (4,4-) 101-68-8	0.0013 [0.00012]	NA	Irritating to eyes, nose, throat; respiratory sensitization, cough, pulmonary secretions, chest pain, dyspnea, asthma.	RS, eyes	NA	

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
Methyl ethyl ketone 78-93-3	14.4 [4.88]	D	Irritation, CNS, reproductive effects [AC].	Fetus, CNS	0.7375-147.5 Sweet, acetone-like odor	Dermal exposure may contribute to overall dose.
Methyl is obutyl ketone 108-10-1	0.55 [0.13]	NA	Irritation, narcosis, liver, kidneys[AC].	Liver, kidneys, CNS	0.41-192.7 Sweet, sharp odor	
Methyl styrene (mixture) 2501-31-54	0.027 [0.0057]	NA	Irritation nasal cavity, respiratory system.	RS	Strong disagreeable odor	
Methyl tert-butyl ether 1634-04-4	2.1 [0.57]	NA	Liver, kidney, effects, prostration[I].	Liver, kidneys, eyes	Terpene-like odor	
Naphthalene 91-20-3	0.0071 [0.0014]	C	Irritation eyes, nose, throat; respiratory sensitization, cough, pulmonary secretions, chest pain, dyspnea; asthma; hyperplasia and metaplasia of respiratory and olfactory epithelium, hematotoxicity, renal failure; cancer	RS, eyes, blood, kidneys	1.5-125 Mothball, tar-like	Skin – dermal exposures have the potential for significant contribution to overall dose[Ac]. Hemolytic anemia may occur at lower doses in those with (genetic) G-6-PD deficiencies. See RD 4.9.2

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
Nickel (elemental/metal) 7440-02-0	0.037 [0.015]	NA	Dermatitis, pneumoconiosis, kidney effects.	Skin , LRS, kidney	NA	
Nickel (soluble compounds)	0.00014	NA	Irritation; dermatitis, chronic active inflammation and lung fibrosis, CNS effects.	CNS, LRS, skin	NA	
Nickel (insoluble compounds)	0.0049	NA	Irritation; dermatitis, cancer (lung).	LRS, skin	NA	
Nickel carbonyl 13463-39-3	0.00085 [0.0012]	NA	Irritation; CNS; respiratory effects; cancer.	LRS, CNS, skin	NA	
Nickel subsulfide 12035-72-2	0.001 [0.001]	NA	Cancer (lung); irritation; dermatitis.	LRS, skin	NA	
Nickel refinery dust	0.020	A	Sensitization dermatitis, allergic asthma, pneumonitis, cancer.	LRS, skin	NA	C

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
Nitroaniline (2-) 88-74-4	0.0014 [0.00024]	NA	Hematological effects.	Blood[H]	Musty odor	
Nitrobenzene 98-95-3	0.014 [0.0027]	D	Irritation eyes, skin, anoxia; dermatitis; anemia; methemoglobinemia; liver, kidney damage, testicular effects.	Eyes, skin, blood, ENDO, kidneys, liver, CVS REPR	0.0235-9.5 Shoe polish, pungent odor	Skin – dermal exposures have the potential for significant contribution to overall dose[Ac].
Nitrogen dioxide	0.1 [0.053]	NA	Irritation eyes, nose, throat; cough, mucoid frothy sputum, decreased pulmonary function, chronic bronchitis, dyspnea; chest pain, pulmonary edema, cyanosis, tachypnea, tachycardia	RS, eyes, CVS	NA	See Section 4.4.1 for more information. CHID under development.
Nitropropane (2-) 79-46-9	0.0018 [0.00049]	B2	Irritation eyes, skin, nose, respiratory system; headache, anorexia, nausea, vomiting, diarrhea; kidney, liver damage, cancer.	Eyes, skin, liver, RS, CNS	17.5-1029 Pleasant, fruity odor	C RfC based on LOAEL of 78 mg/m^3 for liver lesions in 22-month rat inhalation study.
Nitroso-di-n-butylamine (N-) 924-16-3	0.003	B2	Cancer.	Bladder, GI tract, LRS, liver[I]	NA	C

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
Nitrosodiethylamine (N-) 55-18-5	0.00011 [0.000027]	B2	Acts transplacentally, trends for tumors of the nasopharynx, lower jaw, stomach, kidney, ovaries, seminal vesicles, and esophagus. Dose-related increases in incidence of upper GI tumors and liver cell tumors were observed in mice, and tracheal and liver cell tumors were observed in hamsters[I]; cancer.	Liver, GI tract, RS[I]	NA	C
Nitrosodimethylamine (N-) 62-75-9	0.00034 [0.00011]	B2	Nausea, vomiting, diarrhea, abdominal cramps; headache; fever; enlarged liver, jaundice; decreased liver, kidney, pulmonary function, cancer.	LRS, liver, kidneys[I], GI tract	NA	C Skin – dermal exposures have the potential for significant contribution to overall dose[Ac].
Nitrosopyrrolidine (N-) 930-55-2	0.0079 [0.0019]	B2	Liver cancer, lung adenomas, papillary mesotheliomas of the testes[I].	Liver, LRS, REPR[I]	NA	
Ozone 10028-15-6	0.052 [0.027]	NA	Irritation eyes, mucus membranes: pulmonary edema; chronic respiratory disease; headache	Eyes, RS	NA	See Section 4.4.1 for additional information. MEG is based on a moderate work level. CHID under development.
Particulate [<2.5? (PM-2.5)]	0.04	NA	Irritation eyes, skin, throat, respiratory system, pulmonary alveolar proteinosis, pulmonary fibrosis	Eyes, skin, LRS	NA	See Section 4.4.1 for additional information.

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
Particulate [<10? (PM_{10})]	0.07	NA	Irritation eyes, skin, throat, respiratory system,	Eyes, skin, URS	NA	See section 4.4.1 for additional information.
Phenanthrene 85-01-8	0.042 [0.0058]	D	Skin, eyes, nose, and throat irritation, blistering, respiratory effects, skin photosensitization.	Skin, eyes, RS	Faint aromatic odor	Little toxicity data available for this compound. Photosensitizarion of chemical may increase dermal effects.
Phosphine 7803-51-2	0.0021 [0.0015]	D	Nausea, vomiting, abdominal pain, diarrhea; thirst; chest tightness, dyspnea muscle pain, chills; stupor or syncope; pulmonary edema.	CNS, LRS, GI tract	0.028-3.6 Disagreeable odor of rotten fish or garlic	
Phosphoric acid 7664-38-2	0.024 [0.0061]	NA	Irritation eyes, skin, respiratory system; dermatitis; eye, skin burns.	LRS, eyes, skin	NA	
Phthalic anhydride 85-44-9	0.082 [0.014]	NA	Irritation eyes, skin, upper respiratory system; conjunctivitis; nasal ulcer bleeding; bronchitis, bronchial asthma; dermatitis; liver, kidney damage.	RS, eyes, skin, liver, kidneys	[0.05] Acrid odor	
Polychlorinated biphenyls 1336-36-3	0.0084	B2	Cancer	Liver, GI tract, blood, skin, ENDO[I]	Mild aromatic odor	C

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
n-Propylbenzene 103-65-1	0.025 [.0052]	D	Irritation of eyes, nose, throat, and skin, CNS depression, incoordination, nausea, general anesthetic effects.	Eyes, RS, skin	NA	Acute exposures produce general anesthetic effects.
Propylene glycol monomethyl ether 107-98-2	14 [3.7]		Irritation eyes, skin, nose, throat; headache, nausea, light-headedness, drowsiness, incoordination; vomiting, diarrhea.	CNS, eyes. skin, URS	[10] Sweet, ether-like odor	
Propylene oxide 75-56-9	0.29 [0.12]	B2	Irritation eyes, skin, respiratory system; CNS depression, liver damage, blisters, burns, cancer[Ns, Ac, N].	Eyes, skin, URS, CNS, liver	24.75-500 Sweet, alcoholic odor	Slope factor based on tumors of the nasal cavity in 2-year mouse inhalation study.
Pyrene 129-00-0	0.105 [0.013]	D	Skin irritation.	Skin	NA	Limited toxicity data available for this compound.
Strontium 7440-24-6	1.51 [0.42]	NA	Skin and eye irritation, altered heart function, bone abnormalities.	Bone, heart, skin, eyes	NA	Based on USEPA extrapolation from oral exposure data.

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
Styrene 100-42-5	2.0 [0.48]	NA	Irritation, eyes, nose, respiratory system; headache, fatigue, dizziness, confusion, malaise, drowsiness, weakness, unsteady gait, narcosis; defatting dermatitis; liver injury, reproductive effects.	CNS, eyes, skin, RS, liver, REPR	0.2021-860 Solvent-like rubbery odor	
Sulfur dioxide	0.13 [0.05]	NA	Irritation eyes, mucus membranes: pulmonary edema; chronic respiratory disease; headache	Eyes, RS	NA	See Section 4.4.1 for additional information. CHID under development.
Tetrachlorodibenzodioxin (TCDD) (2,3,7,8-) 1746-01-6	0.00000011	B2	Irritation eyes; allergic dermatitis, chloracne; porphyria; GI disturbances; possible reproductive, teratogenic effects; liver, kidney damage; hemorrhage; cancer.	Eyes, skin, liver, kidneys, RS, REPR	NA	C
Tetrachloroethane (1,1,1,2-) 630-20-6	0.65 [0.094]	C	Irritation eyes, skin; weakness, restlessness, irregular respiration, muscle incoordination, liver changes; cancer.	Liver, skin, kidneys, CNS, GI tract	NA	C
Tetrachloroethane (1,1,2,2-) 79-34-5	0.083 [0.012]	C	Nausea, vomiting, abdominal pain; tremor fingers; jaundice, hepatitis; liver tenderness, dermatitis, monocytosis (increased blood monocytes); kidney damage; cancer.	Liver, skin, kidneys, CNS, GI tract	21-35 Sickly sweet odor	C Skin – dermal exposures have the potential for significant contribution to overall dose[Ac].

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
Tetrafluoroethane (1,1,1,2-) 811-97-2	55.0 [13.0]	NA	Reproductive effects (testes).	REPR	NA	
Toluene 108-88-3	4.6 [1.2]	D	Irritation eyes, nose; fatigue, weakness, confusion, euphoria, dizziness, headache; dilated pupils, lacrimation (discharge of tears); nervousness, muscle fatigue, insomnia; paresthesia; dermatitis; liver, kidney damage.	CNS, URS, eyes, skin, liver and kidneys	[2.9] Pungent, benzene-like odor	Skin – dermal exposures have the potential for significant contribution to overall dose[Ac]. CHID under development.
Toxaphene 8001-35-2	0.015 [0.00088]	B2	Nausea, confusion, agitation, tremor, convulsions, unconsciousness; dry, red skin, cancer.	Liver, CNS, skin	2.366 Mild piney, chlorine, camphor odor	C Skin – dermal exposures have the potential for significant contribution to overall dose[AC].
Trichlorobenzene (1,2,4-) 120-82-1	1.4 [0.18]	D	Irritation eyes, skin, mucous membranes; liver, kidney damage, possible teratogen.	Liver, eyes, skin, URS, REPR	24 Aromatic odor	
Trichloroethane (1,1,2-) 79-00-5	0.30 [0.055]	C	Irritation, eyes, nose; CNS depression; liver, kidney damage; dermatitis, cancer.	Liver, eyes, URS, CNS, kidneys	NA	C

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
Trichlorofluoromethane 75-69-4	4.8 [0.85]	NA	Renal and respiratory effects.	Kidneys, LRS, CVS, CNS[H, Ac]	28-1170 Sweet odor	
Trichlorophenol (2,4,6-) 88-06-2	1.5 [0.19]	B2	Leukemia[I]; cancer.	Blood, HEM	Strong phenolic odor	C
Trichloro-1,2,2-trifluoroethane (1,1,2-) 76-13-1	21.0 [2.7]	NA	Irritation skin, throat; drowsiness; dermatitis; CNS depression, asphyxiation, cardiac arrhythmias, narcosis.	Skin, heart, CNS, CVS	342-1026 Sweet odor	
Triethylamine 121-44-8	0.10 [0.024]	NA	Irritation eyes, skin, respiratory system; myocardial, kidney, liver damage[N]; squamous metaplasia in the trachea, thymic atrophy, lung effects (perivascular edema), death[I].	Eyes, skin, RS, CVS, liver, kidneys	0.36-1.12 Fishy, amine odor	Skin – dermal exposures have the potential for significant contribution to overall dose[Ac]. Dermal application may cause chemical burns. Based on one study, the concentration response curve of triethylamine appears to rise abruptly, with frank effects occurring at levels only 4-fold above a no-effect level.

Chemical CAS No.	1-Year Air-MEG mg/m^3 [ppm]	Cancer Group	Potential Toxic Signs and Symptoms [S,N]	Target Organs and Systems	Odor/ Threshold[O] mg/m^3 [ppm]	Notes
Trimethylbenzene (1,2,4-) 95-63-6	3.06 [0.62]	NA	Irritation of skin, eyes, nose, throat, bronchitis, anemia, drowsiness, fatigue, nausea	Eyes, skin, RS, CNS, Blood	Distinctive aromatic odor	
Trimethylbenzene (1,3,5-) 108-67-8	3.06 [0.62]	NA	Irritation of skin, eyes, nose, throat, bronchitis, anemia, drowsiness, fatigue, nausea	Eyes, skin, RS, CNS, blood	Sweet odor	
Vinyl acetate 108-05-4	0.14 [0.039]	NA	Irritation eyes, skin, nose, throat; hoarseness, cough; loss of smell.	RS, eyes, skin	0.36-1.65 Sour, sharp odor	
Vinyl Bromide 593-60-2	0.0021 [0.00047]	B2	Irritation eyes, skin; dizziness, confusion, incoordination, narcosis, nausea, vomiting[N]; liver injury and cancer[H].	Eyes, skin, CNS, liver, GI tract[N]	Characteristic pungent odor	Bromoethene appeared carcinogenic (in liver) in this study at higher doses.
Vinyl chloride 75-01-4	0.057 [0.022]	A	Weakness; abdominal pain, GI bleeding; enlarged liver; pallor or cyanosis of extremities; Raynaud's syndrome, acroosteolysis; cancer.	Liver, CNS, RS, REPR, fetus, CVS, GI tract	[10-20] Sweet, ethereal odor	C
Xylene (mixed, o, m, p) 1330-20-7	10.6 [2.4]	NA	Irritation eyes, nose throat, CNS effects; GI distress; pulmonary inflammation /edema; reproductive and developmental effects	Eyes, URS, CNS, liver, REPR, fetus	NA	

Footnotes on next page.

FOOTNOTES FOR TABLE C-3 – LONG-TERM AIR-MEGS

Ac - ACGIH, 1999 TLVs and BEIs Handbook
BW – body weight
BAP – Benzo(a)pyrene
BUN – Blood urea nitrogen (indicator of kidney infection)
C - MEG based on carcinogenic effect
CHID – Chemical Hazard Information for Deployments. Additional Fact Sheet information is under development for notated Chemicals.
E- Critical studies identified by IRIS, HEAST or NCEA. See RD 230 for specific basis and calculations.
EKG – Electrocardiogram
H – HEAST, USEPA, 1997
I – IRIS, USEPA, 1999
LOAEL - Lowest-observed adverse-effects level
M - National Research Council, Committee on Toxicology. 1997, *Toxicity of Military Smokes and Obscurants*, National Academy Press, Washington, D.C
N - National Institute of Safety and Occupational Health (NIOSH) Pocket Guide to Chemical Hazards, 1994, and IRIS/HEAST (unless noted)
NA - Not Available; for cancer class an NA is sometimes assumed to be a "non-carcinogen" but specific studies may not have been performed
ND - Not Determined
NOAEL - No-observed adverse effects level
NOEL - No-observed effects level
Ns - National Safety council, 1988, *Fundamentals of Industrial Hygiene*
O - The primary sources of odor thresholds in air were the *Odor Thresholds and Irritation Levels of Several Chemical Substances: A Review*, American Industrial Hygiene Association J., 47, 1986 and the N.J. Hazardous Substances Fact Sheets. Ranges represent reported low and high threshold ranges. Significant figures are reported as provided in sources. The primary sources of odor characteristics were Amer. Ind. Hyg. Assoc. J (47), 1086 and the Hazardous Substances Data Base.
PAH – Polyaromatic hydrocarbons
ppm – parts per million
S - Exposure symptoms which may occur at with acute or long-term exposures above Air MEGs-L
SGOT – Serum glutamic-oxaloacetic transaminase (aspartate aminotransferase)
SGPT – Serum glutamate pyruvate transaminase (alanine aminotransferase)
T - Compton, James A.F. 1987. *Military Chemical and Biological Agents*, The Telford Press, Caldwell, NJ.
TEF – Toxicity equivalence factor
UD - Under development; requires further assessment

Target Organ/Systems and Carcinogenicity information next page:

TABLE 2-4-1. TARGET ORGANS

TARGET ORGANS	
Eyes	Brain
Skin	Heart
Blood	Pancreas
Bladder	Adrenal Glands
Thyroid	Lungs
Bone	Liver
Fetus	Kidneys
Spleen	

TABLE 2-4-2. TARGET SYSTEMS

TARGET SYSTEMS	
CNS – Central Nervous System	CVS – Cardiovascular System
PNS – Peripheral Nervous System	ChE Inh – Cholinesterase Inhibitor
GI tract – Gastrointestinal Tract	UT – Urogenital Tract
RS – Respiratory System	CRC – Circulatory System
LRS – Lower Respiratory System	IMM – Immune System
URS – Upper Respiratory System	REPR – Reproductive System
ENDO – Endocrine System	HEM – Hemopoietic System
LYMP – Lymphatic System	

Cancer Class Categories:

The scheme used by the USEPA for categorizing chemicals according to their carcinogenic potential is as follows (see Section 2.4.3):

Group A: Human carcinogen
Group B: Probable human carcinogen:
- Group B1 - Limited evidence in epidemiologic al studies
- Group B2 - Sufficient evidence from animal studies

Group C: Possible human carcinogen
Group D: Not classifiable
Group E: No evidence of carcinogenicity

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TABLE C-4. AMBIENT AIR QUALITY STANDARDS AND MILITARY EXPOSURE GUIDELINES FOR PRIORITY POLLUTANTS

POLLUTANT	NAAQS (Primary)	TLV-TWA*	1 Year Air-MEG
Carbon Monoxide (CO)			
1-hour average	35 ppm (40 mg/m^3)	—	—
8-hour average	9 ppm (10 mg/m^3)	25 ppm (29 mg/m^3)	—
1-year average	—	—	3 ppm (3.3 mg/m^3)
Nitrogen Dioxide (NO_2)			
1-year average	0.053 ppm (100 µg/m^3)	—	0.053 ppm (0.1 mg/m^3)
8-hour average	—	3 ppm (5.6 mg/m^3)	—
Ozone (O_3)			
8-hour average	0.08 ppm (157 µg/m^3)	Moderate work: 0.08 ppm (0.16 mg/m^3)	—
1-year average	—	—	0.027 ppm (0.052 mg/m^3)
Lead			
8-hour average	—	0.05 mg/m^3 [A] 0.03 mg/m^3 [B]	—
3-month Average	1.5 µg/m^3	—	—
1-year average	—	—	0.0015 mg/m^3
Particulate < 10 ? m (PM-10) †			
8-hour average	—	10 mg/m^3	—
24-hour[C]	150 µg/m^3	—	—
1-year average	50 µg/m^3	—	0.07 mg/m^3
Particulate < 2.5 ? m (PM-2.5) †			
8-hour average	—	3 mg/m^3	—
24-hour[D]	65 µg/m^3	—	—
1-year average	15 µg/m^3	—	0.04 mg/m^3
Sulfur Dioxide (SO_2)			
3-hour average	0.50 ppm (1300 µg/m^3)	—	—
8-hour average	—	2 ppm (5.24 mg/m^3)	—
24-hour average	0.14 ppm (365 µg/m^3)	—	—
1-year average	0.03 ppm (80 µg/m^3)	—	0.05 ppm (0.13 mg/m^3)

ppm= Parts per Million

* The American Conference of Industrial Hygienists (ACGIH) time-weighted average (TWA) concentration for a conventional 8-hr workday and a 40-hr workweek, to which it is believed that nearly all workers may be repeatedly exposed, day after day, without adverse effect.

† See Table C5 (next page) for additional information.

[A] This is also the OSHA 8-hr permissible exposure limit (PEL) (29 CFR 1910.1025)

[B] OSHA action level (29CFR 1910.1025). For those workers exposed to air concentrations at or above the action level for more than 30 days, OSHA mandates periodic determination of blood lead levels.

[C] Three-year average of the 99th percentile of 24-hour concentrations over a given year, with one or less days exceeded.

[D] Three-year average of the 98th percentile of 24-hour concentrations over a given year, with one or less days exceeded.

For reference, the USEPA general population index values for particulates are provided below. The user should note that these values do not portray exactly the same levels of risk represented by the MEGs in this Appendix. The index ranges are only provided to make relative comparisons to U.S. guidance regarding recommended activity levels for different levels of air quality.

TABLE C-5. U.S. GENERAL POPULATION INDEX CRITERIA FOR PARTICULATE MATTER (PM_{10})*

Level	Concentration (?g/m^3)	General Civilian Population Health Effects Statements	General Civilian Population Health Effects Statements
1	255-354	Increased respiratory symptoms (e.g. coughing) and aggravation of lung disease (e.g., asthma)	Elderly, children, and people with lung disease (e.g., asthma) should restrict heavy exertion; others should minimize prolonged exertion
2	355 - 424	Significant increase in respiratory symptoms (e.g. coughing, mucous) and aggravation of lung disease (e.g. asthma)	Elderly, children, and people with lung disease (e.g., asthma) should avoid outdoors; others should minimize moderate to heavy exertion
3	425 - 604	Serious risk of respiratory symptoms (e.g. coughing, mucous, shortness of breath) and aggravation of lung disease (e.g. asthma)	All should minimize outdoor exertion

* U.S. Environmental Protection Agency, Guideline for Reporting of Daily Air Quality –Pollutant Standards Index (PSI) DRAFT, 1998.

CHEMICAL INDEX (AIR)

APPENDIX D

MILITARY EXPOSURE GUIDELINES FOR WATER

CONTENTS

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TABLE D-1. SHORT-TERM, WATER MILITARY EXPOSURE GUIDELINES (5 AND 14 DAYS)

Chemical CAS No.	5 L/day MEG † (mg/L) 5-day	 2-week	15 L/day MEG † (mg/L) 5-day	 2-week	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Acifluorfen 5094-66-6	2.8	2.8	0.9	0.9	Liver changes.	Liver	NA	B carcinogen
Acrylamide 79-06-1	2	0.4	.7	0.14	Sleepiness, hallucinations, disorientation, incoordination in the legs, weakness, tremors, and possibly seizures.	CNS, PNS	NA	Effects of high exposure may be delayed in onset for several hours. B carcinogen
Acrylonitrile 107-13-1	0.5	0.5	0.14	0.14	Headache, irritability, light-headedness, impaired judgment, nausea, vomiting, diarrhea, abdominal pain, weakness; higher concentrations may cause liver damage, anemia, irregular breathing, and seizures; exposure in utero may cause birth defects.	CVS, liver, kidneys, CNS, REPR	NA	Ingestion of 1.5 to 2 g (300-400 mg/L) can cause severe, lasting effects. Based on ATSDR MRL. B carcinogen
Adipate (diethylhexyl) 103-23-1	28	28	9.3	9.3	Short-term effects from exposure in drinking water are unknown.	Liver, REPR	NA	C carcinogen.
Alachlor 15972-60-8	0.14	0.14	0.05	0.05		Liver, kidney, spleen	NA	B human carcinogen.
Aldrin 309-00-2	0.0004	0.0004	0.0001	0.0001	Nausea, vomiting, diarrhea, hyperexcitablity, tremors, limb jerks, convulsions, and ventricular fibrillation; reversible kidney and liver injury.	CNS, liver, kidneys	Odor: 0.017 mg/L	Ingestion of 25.6 mg/kg (360 mg/L) can produce convulsions; a single oral dose of 5 g (1 g/L) was lethal. B carcinogen.
Ametryn 834-12-8	12	12	4	4	Incoordination, shortness of breath, muscle weakness, salivation, and loss of reflexes.	Liver, CNS	NA	
Ammonia 7664-41-7	3.4	3.4	3.4	3.4	Very high concentrations are corrosive and can cause ulcerative esophagitis. Such levels are not		Odor and taste: 3.4 mg/L	Exposure guideline for ammonia based on odor and taste threshold; can

Chemical CAS No.	5 L/day MEG † (mg/L) 5-day	 2-week	15 L/day MEG † (mg/L) 5-day	 2-week	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
					likely to be found in drinking water.			react with the water supply disinfectant hypochlorite to produce objectionable tastes and odors.
Ammonium sulfamate 7773-06-0	90	90	30	30	Gastrointestinal disturbances.	GI tract	NA	A military adjustment factor of 3 has been applied.
Antimony 744-36-0	0.006	0.006	0.002	0.002	Irritation of the nose, mouth, nose and intestines; nausea, vomiting, diarrhea, bloody stools, stomach cramps, difficulty breathing, weight and hair loss, dry scaly skin; heart, liver, and kidney congestion.	GI tract, CVS, liver, kidney	NA	Doses between 1 and 1.5 mg/kg (14-21 mg/L) may cause severe vomiting, diarrhea and death.
Arsenic 7440-38-2 ***TB MED 577**	0.3	-	0.1	-	Facial swelling, vomiting, loss of appetite, abdominal pain; diarrhea, shock, muscle cramps, headache, chill, cardiac abnormalities, anemia, decreased white blood cell count, and enlargement of liver; delayed effects include sensory and motor peripheral polyneuropathies.	Liver, kidney, CRC, CNS, GI tract, IMM	NA	The risk of developing symptoms of acute toxicity increases as the concentration in drinking water increases above 0.3 mg/L. The risk of severe toxic effects and fatalities increases as concentrations rise above 14 mg/L. Known human carcinogen. CHID under development.
Atrazine 1912-24-9	0.7	0.7	0.23	0.23	Congestion of heart, lungs and kidneys; hypotension, urine retention, muscle spasms, loss of appetite, salivation, depression of activity, incoordination, fever, and shortness of breath.	Eyes, CNS, CVS	NA	Possible human carcinogen. Atrazine values were adjusted in accordance with the 4/01/97 IRIS.[I]

Chemical CAS No.	5 L/day MEG † (mg/L) 5-day	 2-week	15 L/day MEG † (mg/L) 5-day	 2-week	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Baygon 114-26-1	0.06	0.06	0.02	0.02	Headache, constricted pupils, blurred vision, nausea, vomiting, abdominal cramps, diarrhea, salivation, sweating, tearing, runny nose, lassitude, weakness, chest tightness, loss of coordination, slurred speech, muscle twitching, breathing difficulty, and incontinence; higher concentrations can cause convulsions and coma; fetal death and birth defects have been observed in experimental animals.	CNS, GI tract, ChE Inh.	NA	A single oral dose of 0.36 mg/kg (5 mg/L) caused transient stomach discomfort, blurred vision and sweating. Ingestion of a single oral dose of 1.5 mg/kg (21 mg/L) caused blurred vision, nausea, sweating, rapid heartbeat, and vomiting. The effects occurred within 15-20 minutes after exposure and disappeared within 2 hours. C carcinogen.
Bentazon 25057-89-0	0.4	0.4	0.1	0.1	Vomiting, diarrhea, difficulty breathing, weakness, apathy, incoordination, and tremors.	CNS	NA	
Benzene 71-43-2	0.3	0.3	0.1	0.1	Vomiting, loss of coordination, light-headedness, headache, anemia, shallow/rapid pulse, loss of concentration, delirium, chemical pneumonitis, dizziness, pallor, flushing, weakness, and breathlessness; high concentrations may cause convulsions, coma, or irregular heart beat.	Eyes, skin, RS, blood, CNS, bone, IMM	Odor: 2.0 mg/L Taste: 0.5 - 4.5 mg/L	The mean lethal dose has been estimated to be 13 g (2.6 g/L). Known human carcinogen. CHID under development.

Chemical CAS No.	5 L/day MEG † (mg/L) 5-day	 2-week	15 L/day MEG † (mg/L) 5-day	 2-week	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Beryllium 7440-41-7	36	36	12	12	Low acute toxicity by ingestion.	Bone	NA	B carcinogen.
Boron 7440-42-8	5	1.2	1.7	0.4	Vomiting, abdominal pain, diarrhea; headache, tremors, restlessness, weakness, convulsions; may affect the liver, and may cause skin rash and desquamation.	CNS, skin, kidneys	NA	Single ingestion of 1.8 to 3.6 mg/kg (25-50 mg/L) boron caused no effects in volunteers. Ingestion of 22.5 mg/kg (315 mg/L) produced erythema, desquamation, and CNS effects. The mean lethal oral dose has been estimated to be over 400 mg/kg (5.6 g/L) in humans and the lowest oral lethal dose has been estimated as 112 mg/kg (1.6 g/L). USEPA and state (long-term) standards 0.6-1.0 mg/L.
Bromacil 314-40-9	7	7	2	2	Vomiting, salivation, muscular weakness, excitability, diarrhea, and mydriasis.	Thyroid	NA	C carcinogen.
Bromochloromethane 74-97-5	1.4	1.4	0.5	0.5	Loss of appetite, nausea, vomiting, abdominal pain, severe headache, confusion, dizziness, memory impairment, weakness, tremors and convulsions; elevated carboxyhemoglobin.	Liver, kidneys, CNS	Odor: 34 mg/L	B carcinogen (kidney and liver tumors). Long-term USEPA and State standards range 0.08 – 0.002 mg/L
Bromodichloro-methane 75-27-4	8.4	8.4	2.8	2.8	CNS functional disturbances, including sedation, anesthesia, incoordination, and depression of rapid eye movement sleep; increased blood levels of	CNS, liver, kidneys	NA	B carcinogen.

Chemical CAS No.	5 L/day MEG † (mg/L) 5-day	 2-week	15 L/day MEG † (mg/L) 5-day	 2-week	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
					methemoglobin. Liver, kidney tumors in animals.			
Bromoform 75-25-2	7	3	2	1	Headache, dizziness, disorientation, listlessness, amnesia and slurred speech, shock, unconsciousness, and convulsions.	CNS, liver, kidneys	NA	Probable human carcinogen.
Bromomethane 74-83-9	0.2	0.2	0.07	0.07	Tremor, convulsions, shortness of breath.	CNS	NA	
Butylate 2008-41-5	3	3	1	1			NA	
BZ 6581-06-2 ***TB MED 577**	0.007	-	0.0023	-	Elevated heart rate and blood pressure, facial flushing, dryness of the throat and mouth, loss of appetite, weakness, fatigue, and blurred vision; higher concentrations may cause tremors of the lips and arms, facial muscle twitches, speech difficulties, severe mental depression, and confusion.	CNS	NA	The risk of severe and enduring performance-degrading effects increases as the concentration of BZ in drinking water increases above 0.007 mg/L. Concentrations of 0.014 mg/L can cause blurred vision, dry mouth and mild incapacitation; 0.028 mg/L may cause delirium.
Cadmium 7440-43-9	0.06	0.06	0.02	0.02	Nausea, vomiting, diarrhea, muscle cramps, salivation, sensory disturbances, liver injury, convulsions, shock, and renal failure.	Kidneys, liver	NA	Ingestion of 3 mg (0.6 mg/L) may cause vomiting; 30 mg (6 mg/L) of soluble cadmium salts can produce severe toxic symptoms; 350 mg (70 mg/L) may be fatal.

Chemical CAS No.	5 L/day MEG † (mg/L) 5-day	 2-week	15 L/day MEG † (mg/L) 5-day	 2-week	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Carbaryl 63-25-2	1.4	1.4	0.5	0.5	Nausea, vomiting, abdominal cramps, diarrhea, salivation, sweating, lassitude, weakness, runny nose, chest tightness, blurred or dim vision, miosis, tearing, loss of coordination, slurred speech, muscle twitching, tremor, breathing difficulty, cyanosis, hypertension, jerky movements, incontinence, convulsions, coma, and respiratory paralysis.	CNS, REPR, CVS, ChE Inh	NA	Single doses of 0.5 to 2.0 mg/kg (7 -28 mg/L) and repeated daily doses of 0.13 mg/kg (1.82 mg/L) taken for 6 weeks caused no adverse effects in volunteers. But ingestion of single doses of 2.8 mg/kg (39 mg/L) or 5.45 mg/kg (76 mg/L) produced moderately severe poisoning with vomiting, pain and lassitude in other individuals; 5.7 g/kg (80 g/L) has been fatal.
Carbofuran 1553-66-2	0.07	0.07	0.02	0.02	Headache, weakness, nausea, light-headedness, miosis, blurred vision, abdominal cramps, excessive perspiration and salivation, diarrhea, vomiting, muscle twitching, incoordination, and convulsions.	PNS, ChE Inh	NA	A single dose of 0.05 mg/kg (0.7 mg/L) caused no symptoms in volunteers; 0.1 mg/kg (1.4 mg/L) caused headache and light headedness; 0.25 mg/kg (3.5 mg/L) produced salivation, abdominal pain, drowsiness, dizziness, anxiety and vomiting.
Carbon disulfide 75-15-0	0.14	0.14	0.05	0.05	Dizziness, headache, nausea, vomiting, diarrhea, fatigue, palpitations and weakness; high concentrations may cause psychosis, tremor, delirium, coma, muscle spasm,	CNS, PNS, liver, REPR	NA	MEGs were derived from the ATSDR acute oral MRLs.

Chemical CAS No.	5 L/day MEG † (mg/L) 5-day	 2-week	15 L/day MEG † (mg/L) 5-day	 2-week	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
					convulsions, difficulty breathing, and liver damage.			
Carbon tetrachloride 56-23-5	5.6	0.2	2	0.07	Nausea, vomiting, abdominal pain, diarrhea, headache, drowsiness, dizziness, weakness, blurred vision, incoordination, confusion, disorientation, anesthesia, and tremors; liver and kidney damage.	CNS, liver, kidneys	Odor: 0.52 mg/L	A single oral dose of 3 ml (1 g/L) caused dizziness and a dose of 6 ml (2.0 g/L) caused sleepiness, giddiness, and headache in volunteers. Doses in excess of 500 mg/kg (7 g/L) have been reported to cause nausea, vomiting, abdominal pain, CNS and liver damage. But some individuals have suffered severe adverse effects from ingestion of 34 mg/kg (480 mg/L). Consumption of alcohol strongly exacerbates the effects of carbon tetrachloride. B carcinogen.
Carboxin 5234-68-4	1.4	1.4	0.5	0.5	Depression, difficulty breathing, seizures.	CNS	NA	
Chloral hydrate 302-17-0	1	0.3	0.3	0.1	Light-headedness, malaise, deep stupor, incoordination, and nausea; occasional vomiting, flatulence, stomach ulcers; respiratory depression and hypotension; large doses may cause cardiac arrhythmia.	CNS, GI tract, CVS, liver, kidneys	NA	C carcinogen.

Chemical CAS No.	5 L/day MEG † (mg/L) 5-day	 2-week	15 L/day MEG † (mg/L) 5-day	 2-week	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Chloramben 133-90-4	3.5	3.5	1.2	1.2	Skin or eye contact may cause irritation.		NA	
Chlordane 57-74-9	0.09	0.09	0.03	0.03	Nausea, vomiting, diarrhea, headache, excitability, confusion, weakness, incoordination; high concentrations may cause delirium, muscle spasms, convulsions or seizures, coma, pulmonary edema, and difficulty breathing.	CNS, liver, kidneys	NA	Ingestion of 28 to 56 mg/kg (390-780 mg/L) may cause severe effects such as convulsions. The fatal human dose lies between 6 and 60 gm (1 and 10 g/L). The onset of symptoms occurs 45 minutes to several hours after ingestion. B carcinogen.
Chloride 16887-00-6 ***TB MED 577**	600	600	600	600	Reduced water consumption due to high chloride concentrations can lead to dehydration, with symptoms including weariness, apathy, impaired coordination, delirium, heat stroke.		NA	Exposure guidelines are based on palatability; at 600 mg/L, 2% of the military population might refuse to drink water and may suffer dehydration; at 1,000 mg/L, 10% would be at risk of dehydration.
Chlorobenzene 108-90-7	3	3	1	1	Drowsiness, dizziness, light-headedness, muscle spasms, and coma; impaired liver and kidney function.	CNS, liver, kidneys	Odor: 0.05 mg/L Taste: 0.010 - 0.02 mg/L	
Chlorodibromo-methane 124-48-1	8.4	8.4	2.8	2.8	Incoordination, depression of rapid eye movement, sleep, sedation, anesthesia, increased blood levels of methemoglobin; injury of the liver, kidneys and adrenals.	CNS, liver, kidneys	NA	C carcinogen.

Chemical CAS No.	5 L/day MEG † (mg/L) 5-day	 2-week	15 L/day MEG † (mg/L) 5-day	 2-week	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Chloroisopropyl ether (bis-2-) 108-60-1	5.6	5.6	2	2			Odor: 0.2 - 0.32 mg/L	
Chloroform [Tricloromethane] 67-66-3	6	6	2	2	Dizziness, mental dullness, headache, nausea, confusion, fatigue, narcosis, liver and kidney damage/cancer; renal necrosis.	Kidneys, CNS, bladder, fetus	NA	B2 carcinogen; long-term USEPA MCL = 0.0mg/L
Chloromethane [Methyl chloride] 74-87-3	12	0.5	4	0.17	Headache, drowsiness, giddiness, dizziness, confusion, incoordination, vomiting, abdominal pain, diarrhea, breathing difficulties; high concentrations may cause unconsciousness, convulsions, coma, visual disturbances, and may damage the kidneys, liver, or blood.	CNS, liver, kidneys, REPR	NA	Symptoms of chloromethane exposure may be delayed in onset. C carcinogen.
Chlorophenol (2-) 95-57-8	0.8	0.8	0.3	0.3	Restlessness, rapid breathing, and muscle weakness, followed by tremors, seizures, and coma.	CNS, liver, kidneys	Odor: 0.0001 mg/L	Can react with the water supply disinfectant hypochlorite to produce objectionable tastes and odors.
Chlorothalonil 1897-45-6	0.35	0.35	0.12	0.12	Vomiting, rapid breathing, gastrointestinal irritation, weakness, and sedation.	CNS, GI tract, UT	NA	B carcinogen.
Chlorotoluene o- 95-49-8	2.8	2.8	0.9	0.9			Odor: 0.0069 mg/L	
Chlorotoluene p- 106-43-4	2.8	2.8	0.9	0.9			NA	

Chemical CAS No.	5 L/day MEG † (mg/L) 5-day	 2-week	15 L/day MEG † (mg/L) 5-day	 2-week	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Chlorpyrifos 2921-88-2	0.04	0.04	0.014	0.014	Headache, fatigue, dizziness, mental confusion, disorientation, tearing, salivation; cyanosis, constricted pupils, blurred vision, weakness, nausea, vomiting, abdominal cramps, diarrhea, muscle spasms and twitching, convulsions, coma, loss of reflexes, and incontinence. May possibly cause delayed peripheral neuropathy and birth defects.	CNS, PNS, ChE Inh	NA	A single oral dose of 0.5 mg (0.1 mg/L) caused a 15% depression of plasma cholinesterase and no signs of toxicity in volunteers. Ingestion of 0.1 mg/kg/day (1.4 mg/L) for 9 days depressed plasma cholinesterase and had no other effects in volunteers; 0.03 mg/kg/day (0.42 mg/L) for 20 days caused no significant effects. Ingestion of 300 mg (60 mg/L) caused loss of consciousness and acute signs of cholinergic toxicity followed by long-term neurologic effects.
Chromium (total) 7440-47-3	2	2	0.7	0.7	Hexavalent chromium compounds are more toxic than trivalent chromium compounds; ingestion of hexavalent chromium compounds may cause intense gastrointestinal irritation, violent epigastric pain, nausea, vomiting, diarrhea, bleeding, circulatory collapse, unconsciousness, and death; liver and kidney damage are possible with large exposures.	Kidneys, liver	NA	Doses of 0.5 to 1.5 g (100 - 300 mg/L) have caused fatalities.
Cyanazine 21725-46-2	0.14	0.14	0.05	0.05	Weakness, nausea and difficulty breathing; may affect kidney	Blood, kidneys	NA	C carcinogen.

Chemical CAS No.	5 L/day MEG † (mg/L) 5-day	 2-week	15 L/day MEG † (mg/L) 5-day	 2-week	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
					function. Birth defects have been observed in the offspring of experimental animals.			
Cyanide 57-12-5 ***TB MED 577**	6	6	2	2	Headache, breathlessness, weakness, palpitation, nausea, vomiting, giddiness, tremor, rapid heart beat, dizziness, confusion, anxiety, agitation, confusion, cardiac arrhythmias, seizures, stupor, and coma.	CNS, RS, CVS, liver, kidneys	NA	Concentrations between 12 and 24 mg/L may cause changes in blood chemistry without clinical effects. Severe but reversible symptoms may occur at concentrations of 24 to 48 mg/L; concentrations higher than 48 mg/L cause life-threatening toxicity.
2,4-D (2,4-Dichlorophenoxy-acetic acid) 94-75-7	1.5	0.4	0.5	0.14	Nervous system damage, vomiting, diarrhea, lethargy, incoordination, weakness, paralysis, stupor, miosis, stiffness in the extremities, muscle twitching and spasms, lowered blood pressure, convulsions; transient liver and kidney damage; may cause birth defects and reduced fertility.	CNS, liver, kidneys	NA	Ingestion of a single dose of 5 mg/kg (70 mg/L) and repeated doses of 7 mg/kg/day (98 mg/L) for 21 days caused no effects. The single oral lethal dose has been estimated to be 355 mg/kg (5 g/L). Survival following a dose of about 110 mg/kg (1.5 g/L) has been reported.
Dalapon 75-99-0	4.2	4.2	1.4	1.4	CNS depression, lassitude, loss of appetite, diarrhea, vomiting, slowing of pulse.	GI tract, CNS	NA	

Chemical CAS No.	5 L/day MEG † (mg/L) 5-day	 2-week	15 L/day MEG † (mg/L) 5-day	 2-week	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
DCPA [Dacthal] 1861-32-1	105	105	35	35				Single oral doses of 50 mg (10 mg/L) caused no observable effects in volunteers.
Diazinon 333-41-5	0.03	0.03	0.009	0.009	Nausea, vomiting, diarrhea, headache, dizziness, weakness, excessive tearing and salivation, ocular pain, blurring/ dimness of vision, miosis, loss of muscle coordination, slurred speech, muscle twitching, disorientation, drowsiness, difficulty breathing, hypertension, hypotension, cardiac arrhythmias, random jerky movements, incontinence, convulsions, and coma.	Eyes, RS, CNS, CVS, blood, ChE Inh		
Dibromoacetonitrile 3252-43-5	2.8	2.8	0.94	0.94				C carcinogen.
Dibromochloro-propane 96-12-8	0.28	0.07	0.09	0.024	Gastrointestinal distress; may damage the kidney, liver, and testes.	Liver, kidneys, spleen, REPR, GI tract, CNS	Odor: 0.01 - 3.1 mg/L	
Dicamba 1918-00-9	0.4	0.4	0.14	0.14	Vomiting, loss of appetite, headache, dizziness, weakness, difficulty breathing, muscle weakness and spasms.	CNS	NA	
Dichloroacetic acid 79-43-6	1.5	1.5	0.5	0.5	Decreased plasma lactate and glucose levels; high concentrations may cause birth defects.	REPR	NA	B carcinogen.

Chemical CAS No.	5 L/day MEG † (mg/L)		15 L/day MEG † (mg/L)		Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
	5-day	2-week	5-day	2-week				
Dichloroacetonitrile 3018-12-0	1.4	1.4	0.5	0.5	Nausea, vomiting, weakness, stupor, convulsions, and delirium; liver and kidney damage.	CVS, CNS, liver, kidneys	NA	C carcinogen.
Dichlorobenzene m- 541-73-1	12.6	12.6	4.2	4.2	Headache, drowsiness, unsteadiness; irritation of gastric mucosa, nausea, vomiting, diarrhea, abdominal cramps and cyanosis.	CNS, liver, kidneys	NA	
Dichlorobenzene o- 95-50-1	12.6	12.6	4.2	4.2	Headache, nausea, vomiting, and diarrhea; higher doses can produce dizziness, sleepiness, loss of coordination and judgment; methemoglobinemia, hemolytic anemia, and kidney damage.	Liver, kidneys, CNS	NA	
Dichlorobenzene p- 106-46-7	15	15	5	5	High concentrations may cause nausea, vomiting, headaches, liver and kidney injury, anemia, and jaundice.	Liver, kidneys, CNS	NA	C carcinogen.
Dichlorodifluoro-methane 75-71-8	60	60	20	20	Relatively non-toxic by ingestion.	CNS, CVS	NA	The systems listed under target organs are those known to be affected by inhalation.
Dichloroethane (1,2-) 107-06-2	1	1	0.3	0.3	Headache, dizziness, drowsiness, cyanosis, nausea, vomiting and diarrhea; high concentrations can cause gastrointestinal disorders, transient kidney damage, liver injury, and reduced blood pressure.	Kidneys, liver, CNS, CVS	Odor: 29 mg/L; Taste: 29 mg/L	Ingestion of 20 – 50 ml (5 to 12.6 g/L) can cause severe neurological effects and may be fatal. B carcinogen.
Dichloroethylene (1,1-) 75-35-4	2.8	1.4	1	0.5	Dizziness, headache, nausea, liver and kidney dysfunction.	Liver, kidneys, CNS	NA	C carcinogen.
Dichloroethylene (cis-1,2-)	5.6	4.5	2	1.5	CNS depression, decreased red blood cell count.	CNS, blood	NA	The trans form is approximately twice as

Chemical CAS No.	5 L/day MEG † (mg/L) 5-day	 2-week	15 L/day MEG † (mg/L) 5-day	 2-week	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
156-59-2								potent as the cis form in its depression of the CNS.
Dichloroethylene (trans-1,2-) 156-60-5	28	2	9.4	0.7	CNS depression, difficulty breathing, incoordination, decreased red blood cell count.	CNS, blood	NA	The trans form is approximately twice as potent as the cis form in its depression of the CNS.
Dichloromethane [Methylene chloride] 75-09-2	14	2.8	5	1	Dizziness, sleepiness, fatigue, weakness, light-headedness, numbness, tingling in limbs.	CVS, CNS, blood	NA	B carcinogen.
Dichlorophenol (2,4-) 120-83-2	0.04	0.04	0.01	0.01	Abdominal pain, vomiting, bloody diarrhea; pallor, sweating, weakness, headache, dizziness; possibly fleeting excitement and confusion, tremors, convulsions, unconsciousness; dark-colored urine, kidney damage, methemoglobinemia and hemolytic anemia.	CNS, liver, kidneys	NA	
Dichloropropane (1,2-) 78-87-5	0.13	0.13	0.04	0.04	Headache, dizziness; damage to the liver, kidneys, adrenal glands, bladder, and the gastrointestinal tract; hemolytic anemia.	Liver, kidneys, GI tract	NA	B carcinogen.
Dichloropropene (1,3-) 542-75-6	0.042	0.042	0.014	0.014	Weakness, headache, dizziness, lethargy, incoordination, and depressed respiration; may damage the lungs, liver, and kidneys and cause lesions in the gastrointestinal tract.	RS, CNS, liver, kidneys, GI tract	NA	B carcinogen.
Dieldrin 60-57-1	0.0007	0.0007	0.00023	0.00023	Early signs of toxicity are headache, dizziness, nausea, vomiting, malaise, sweating, tremors, limb jerks, EEG changes, convulsions, and coma; secondary	CNS	Odor: 0.04 mg/L	No effects were seen in volunteers given doses of 0.21 mg (0.04 mg/L). Serious effects may occur at a dose of 10 mg/kg

Chemical CAS No.	5 L/day MEG † (mg/L) 5-day	 2-week	15 L/day MEG † (mg/L) 5-day	 2-week	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
					effects include hypertension, cardiac arrhythmias, and fever; sleep, memory, behavioral disturbances, headache, and convulsions may persist for months following exposure.			(140 mg/L); 29 mg/kg (420 mg/L) caused profuse vomiting or prolonged convulsions; the acute mean lethal dose for humans has been estimated to lie between 20 and 70 mg/kg (280 to 980 g/L). B carcinogen.
Di(2-ethylhexyl) phthalate 117-81-7	14	14	4.7	4.7	Mild gastrointestinal disturbances, nausea, dizziness; may cause birth defects.	CNS, liver, REPR	NA	A single dose of 10 g (2 g/L) caused mild gastric disturbances and catharsis. B carcinogen.
Diisopropylmethyl-phosphonate [DIMP] 1445-75-6	30	30	10	10	High concentrations may cause lethargy and other signs of CNS depression.	CNS	NA	A military adjustment factor of 3 has been applied.
Dimethrin 70-38-2	16.8	16.8	5.5	5.5	Drowsiness, dizziness, headache, nausea, vomiting, diarrhea, gastritis, loss of appetite, fatigue, and weakness.	CNS, liver, GI tract	NA	
Dimethyl methyl phosphonate 756-79-6	2.5	2.5	0.8	0.8	High concentrations may cause lethargy and other signs of CNS depression.	CNS	NA	C carcinogen.
Dinitrobenzene (1,3-) 99-65-0	0.06	0.06	0.02	0.02	Methemoglobinemia associated with headache, irritability, dizziness, weakness, nausea, lethargy, shortness of breath, liver damage.	Blood, liver, CNS, CVS	NA	The lethal dose has been estimated to lie between 5 and 50 mg/kg (70 and 700 mg/L).
Dinitrotoluene (2,4-) 121-14-2	0.6	0.6	0.2	0.2	Methemoglobinemia with symptoms of nausea, vomiting,	Blood, CNS, testes	NA	Consumption of alcohol may exacerbate the

Chemical CAS No.	5 L/day MEG † (mg/L) 5-day	 2-week	15 L/day MEG † (mg/L) 5-day	 2-week	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
					headache, weakness, dizziness, and drowsiness; high concentrations may cause difficulty breathing, hypotension, arrhythmia, damage to liver and testes, and anemia; exposure may affect developing fetus.			toxicity of dinitrotoluene. B carcinogen.
Dinitrotoluene (2,6-) 606-20-2	0.6	0.6	0.2	0.2	Methemoglobinemia with symptoms of nausea, vomiting, headache, weakness, dizziness, and drowsiness; high concentrations may cause difficulty breathing, hypotension, arrhythmia, damage to liver and testes; exposure may affect fetus.	Blood, CNS, REPR	NA	Consumption of alcohol may exacerbate the toxicity of dinitrotoluene. B carcinogen.
Dinoseb 88-85-7	0.42	0.42	0.14	0.14	Nausea, vomiting, abdominal pain, marked thirst, fatigue, sweating, facial flushing, rapid heart beat, hyperthermia, respiratory distress, cyanosis, restlessness, anxiety, muscle cramps, excitement, convulsions, and coma.	CNS, REPR	NA	
Dioxane (1,4-) 123-91-1	5.6	0.56	2	0.2	Nausea, headache, liver and kidney damage.	Liver, kidneys, CNS	NA	B carcinogen.
Diphenamid 957-51-7	0.4	0.4	0.13	0.13	Vomiting, salivation, incoordination, prostration, spasms and convulsions.	CNS, liver	NA	
Diphenylamine 122-39-4	1.6	1.6	0.6	0.6	Fast pulse, hypertension, methemoglobinemia, bladder injury; may cause birth defects.	CVS, bladder, REPR	NA	

Chemical CAS No.	5 L/day MEG † (mg/L) 5-day	 2-week	15 L/day MEG † (mg/L) 5-day	 2-week	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Disulfoton 298-04-4	0.014	0.014	0.005	0.005	Headache, loss of appetite, nausea, vomiting, abdominal cramps, diarrhea, weakness, dizziness, confusions, slurred speech, salivation, tearing, profuse sweating, shortness of breath, tightness of the chest, changes in heart rate, cyanosis, miosis, blurred vision, runny nose, slow pulse, muscle twitching, tremors, muscle cramps, incoordination, convulsions, coma, and shock.	Eyes, RS, CNS, CVS, ChE Inh	NA	Oral doses of 0.75 mg/day (0.15 mg/L) for 30 days produced no significant effects in volunteers. The human LD_{50} has been estimated to be 5 mg/kg (70 mg/L).
Dithiane (1,4-) 505-29-3	0.5	0.5	0.2	0.2	Incoordination, lacrimation, lethargy, diarrhea.	GI tract, CNS	NA	
Diuron 330-54-1	1.4	1.4	0.5	0.5	Diuretic effects; high concentration may cause CNS depression; has caused birth defects and fetal deaths in experimental animals.	Blood, CNS	NA	
EA 2192	0.015	-	0.005	-	Nausea, vomiting, diarrhea, cramps, headache, giddiness, dizziness, excessive salivation, tearing, miosis, blurred or dim vision, difficulty breathing, cardiac arrhythmias, loss of muscle coordination, muscle twitching, random jerking movements, convulsions, coma.	CNS, ChE Inh	NA	EA 2192 is a breakdown product of VX. Because its toxicity is believed to be similar (within order of magnitude) to that of VX, the TB MED577 standard for VX was applied to EA 2192 (USACHPPM, 1999).
Endothall 145-73-3	1.1	1.1	0.4	0.4	Hypotension, depressed breathing and heart rate, vomiting, diarrhea, dilated pupils, loss of coordination, transient excitation	CNS	NA	Ingestion of 100 mg/kg (1.4 g/L) can be fatal.

Chemical CAS No.	5 L/day MEG † (mg/L) 5-day	 2-week	15 L/day MEG † (mg/L) 5-day	 2-week	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
					followed by general depression, sluggishness, spasmodic twitching, seizures.			
Endrin 72-20-8	0.035	0.02	0.01	0.007	Headache, dizziness, nausea, vomiting, hypersalivation, insomnia, lethargy, weakness, agitation and confusion; high concentrations may cause convulsions, stupor, tremors, and coma; headache, dizziness, sleepiness, weakness, and loss of appetite may persist for 2 to 4 weeks.	CNS	NA	Convulsions may be induced in humans by doses of 0.2 to 0.25 mg/kg (2.8 to 3.5 mg/L); a dose of 1 mg/kg (14 mg/L) can induce repeated seizures.
Epichlorohydrin 106-89-8	0.2	0.2	0.07	0.07	Nausea, vomiting, abdominal pain, skin irritation; muscular relaxation or paralysis, tremor, convulsions; liver and kidney damage, cyanosis, impairment of male fertility and/or spermatogenesis.	Kidneys, liver, CNS, skin, REPR	Odor: 0.5 – 3 mg/L	B carcinogen.
Ethyl benzene 100-41-4	45	4.5	15	1.5	Headache, nausea, weakness, dizziness, sleepiness, fatigue, loss of coordination, and coma.	CNS	Odor: 0.062 mg/L; Taste: 0.025 mg/L	
Ethylene dibromide 106-93-4	0.01	0.01	0.004	0.004	Liver and kidney damage, vomiting, excitement and other CNS effects.	CNS, liver, kidneys, REPR	NA	A single oral dose of 65 mg/kg (900 mg/L) may be lethal. B carcinogen.
Ethylene glycol 107-21-1	26	8	9	2.5	Weakness, dizziness, inebriation, stupor; high concentrations may cause convulsions, coma, hypertension, rapid breathing, rapid heartbeat, and severe kidney	CNS, CVS, kidneys	NA	Doses up to 190 mg/kg (2.6 g/L) produced no adverse effects in one individual. In other individuals, single doses

Chemical CAS No.	5 L/day MEG † (mg/L) 5-day	 2-week	15 L/day MEG † (mg/L) 5-day	 2-week	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
					damage.			of 1000 mg/kg (14 g/L) produced CNS effects including visual disturbances, light-headedness, headache and lethargy. Doses of 3000 mg/kg (42 g/L) caused ataxia, sleepiness disorientation and stupor, slurred speech, and in some cases, were fatal. The mean lethal oral dose is about 110 g (22.3 g/L).
ETU (Ethylene thiourea) 96-45-7	0.35	0.35	0.1	0.1	Thyroid hyperplasia with changes in levels of thyroid hormones; may cause birth defects.	Thyroid, REPR, liver, IMM	NA	B carcinogen.
Fenamiphos 22224-92-6	0.013	0.013	0.004	0.004	Nausea, vomiting, abdominal cramps, diarrhea, salivation, headache, dizziness, weakness, runny nose, blurred vision, constricted pupils, incoordination, slurred speech, muscle twitches, random jerky movements, mental confusion, disorientation, drowsiness, difficulty breathing, cardiac irregularities, incontinence, convulsions, and coma.	CNS, CVS, ChE Inh	NA	
Fluometron 2164-17-2	2.1	2.1	0.7	0.7	Depression, deep rapid breathing, vomiting, coma.	CNS, blood, thyroid, liver, ChE Inh	NA	
Fluorotrichloro-methane	9.8	9.8	3.3	3.3	Transient jaundice and liver enzyme elevation.	CNS, CVS, liver	NA	Inhaled freons can affect the CNS and the heart, but

Chemical CAS No.	5 L/day MEG † (mg/L) 5-day	 2-week	15 L/day MEG † (mg/L) 5-day	 2-week	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
75-69-4								effects are less severe following ingestion.
Fonofos 944-22-9	0.03	0.03	0.009	0.009	Loss of appetite, nausea, vomiting, abdominal cramps, diarrhea, headache, dizziness, weakness, confusion, blurred vision, constricted pupils, slurred speech, profuse sweating, salivation, and runny nose; cardiac irregularities, difficulty breathing, muscle twitching, paralysis, convulsions, coma, or respiratory arrest may occur.	CNS, CVS, blood, ChE Inh	NA	
Formaldehyde 50-00-0	14	8	5	2.6	Nausea, vomiting, abdominal pain, diarrhea, lethargy, dizziness, hypotension, seizure.	GI tract, CVS	Odor: 20 mg/L; Taste: 50 ppm	The mean lethal dose is 1 to 2 oz. (4.9 – 9.8 g/L). B carcinogen.
GA [Tabun] 77-81-6 ***TB MED 577**	0.14	-	0.046	-	Nausea, vomiting, abdominal cramps, diarrhea, headache, giddiness, dizziness, weakness, excessive tearing, blurred or dim vision, miosis, loss of muscle coordination, slurred speech, muscle twitching, confusion, disorientation, drowsiness, difficulty breathing, excessive salivation, cardiac arrhythmias, random jerking movements, incontinence, convulsions, coma.	CNS, ChE Inh	NA	Human oral LD_{50} values have been estimated at 0.357-0.714 mg/kg (5-10 mg/L).
GB [Sarin] 107-44-8	0.028	-	0.0093	-	See GA.	CNS, ChE Inh	NA	Minimal effects (e.g., excessive dreaming and talking during sleep) may occur after a single dose

Chemical CAS No.	5 L/day MEG † (mg/L) 5-day	 2-week	15 L/day MEG † (mg/L) 5-day	 2-week	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
***TB MED 577**								of 0.002 mg/kg (0.03 mg/L); mild effects (e.g., anorexia, fatigue, anxiety, tightness in the chest) can occur at 0.022 mg/kg (0.31 mg/L). The lethal oral dose has been estimated to be 0.071-0.285 mg/kg (1-4 mg/L).
GD [Soman] 96-64-0 ***TB MED 577**	0.012	-	0.004	-	See GA.	CNS, ChE Inh	NA	Oral LD_{50} values have been estimated at 0.005 to 0.020 mg/kg (0.07-0.28 mg/L).
Glyphosate 1071-83-6	25	25	8	8	Vomiting, diarrhea, abdominal pain; large doses may cause hypotension, tachycardia (rapid heart rate) and palpitations.	Kidneys	NA	
Heptachlor 76-44-8	0.014	0.014	0.005	0.005	Nausea, vomiting, diarrhea, irritation of the gastrointestinal tract; higher exposures may cause liver damage, hyperexcitability, tremors, convulsions, and paralysis.	CNS, liver, GI tract	NA	A dose of 1 to 3 g (200-600 mg/L) has been estimated to cause serious symptoms in humans, especially liver impairment. B carcinogen.

Chemical CAS No.	5 L/day MEG † (mg/L) 5-day	 2-week	15 L/day MEG † (mg/L) 5-day	 2-week	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Heptachlor epoxide 1024-57-3	0.014	-	0.005	-	Apprehension, agitation, muscle twitching and spasms, tremor, incoordination, vomiting, gastrointestinal upset, abdominal pain; higher doses may cause liver damage, and convulsions.	CNS, liver	NA	B carcinogen.
Hexachlorobenzene 118-74-1	0.08	0.08	0.026	0.026	Headache, nausea, cyanosis, muscle spasm, convulsions, liver injury, birth defects.	CNS, blood, liver, kidneys	NA	B carcinogen.
Hexachlorobutadiene 87-68-3	0.4	0.4	0.14	0.14	Kidney damage, possible CNS depression.	Kidneys, liver, CNS	NA	C carcinogen.
Hexachloroethane 67-72-1	7	7	2.4	2.4	Vomiting, diarrhea, severe mucosal injury, liver necrosis, cyanosis, unconsciousness, loss of reflexes.	CNS, liver	NA	C carcinogen.
Hexane (n-) 110-54-3	18	6	5	2	Nausea, vomiting, abdominal swelling, weakness, dizziness, lightheadedness, headache, loss of coordination, damage to the peripheral nerves.	CNS, PNS	NA	About 50 g (10 g/L) may be fatal to humans.
Hexazinone 51235-04-2	10.5	10.5	3	3	Vomiting, liver injury.	Liver	NA	A military adjustment factor of 3 has been applied.
HMX 2691-41-0	7	7	2.3	2.3	Changes in the blood, methemoglobinemia, liver damage.	CNS, blood, CVS, kidneys, liver	NA	
Isophorone 78-59-1	6	6	2	2	Headache, nausea, dizziness, fatigue, incoordination, malaise, and narcosis.	CNS, liver, kidneys	NA	C carcinogen.
Isopropyl methyl-phosphonate 1832-54-8	120	120	40	40	High concentrations may cause diarrhea, reduced motor activity, lung injury.	GI tract, lungs	NA	A military adjustment factor of 3 has been applied.

Chemical CAS No.	5 L/day MEG † (mg/L) 5-day	 2-week	15 L/day MEG † (mg/L) 5-day	 2-week	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Lead compounds No specified CAS. (measured as Total Lead)	0.05	0.05	0.05	0.05	Anxiety, irritability, insomnia, lack of appetite, anemia, headache, muscle weakness, restlessness, reproductive effects in developing fetus are pronounced. Possible kidney and reproductive effects after longer chronic exposures.	CNS, fetus	NA	Primary health impacts are to children/developing fetus. But high concentrations and/or long exposures can result in health impacts to adults. MEGs were selected from general information for lead ions and compounds, including statements in the literature referenced to lead compounds, lead salts, etc. Some lead compounds (e.g. tetraethyl lead) have own unique, toxicity. This MEG should be used when assessing Total Lead analytical results. CHID under development.
Lewisite 542-25-3 ***TB MED 577**	0.08	-	0.027	-	Nausea, vomiting, diarrhea, abdominal pain, intense thirst, restlessness, weakness, hypotension, and hypothermia.	GI tract, heart, brain, kidneys	NA	The risk of potentially fatal performance-degrading injury to the gastrointestinal tract increases as the concentration in drinking water increases above 0.08 mg/L.
Lindane 58-89-9	0.6	0.6	0.2	0.2	Irritability, restlessness, insomnia, anxiety, dizziness, malaise, headache, nausea, fever, cyanosis,	CNS, REPR	NA	Increasing susceptibility to nervous system changes may occur at

Chemical CAS No.	5 L/day MEG † (mg/L) 5-day	 2-week	15 L/day MEG † (mg/L) 5-day	 2-week	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
***TB MED 577**					vomiting, and loss of muscle coordination; higher exposure can cause muscle spasms, seizures, and convulsions.			concentrations between 0.6 and 3.5 mg/L. Signs of poisoning begin to develop at 3.5 mg/L. The mean lethal dose is approximately 400 mg/kg (5.6 g/L). C carcinogen.
Magnesium 7439-95-4 ***TB MED 577**	100	100	30	30	Single doses can have laxative effects that can lead to dehydration, with symptoms of discomfort, weariness, apathy, impaired coordination, delirium and heat stroke.	GI tract	NA	Laxative effects occur at doses greater than 480 mg (96 mg/L).
Malathion 121-75-5	0.3	0.3	0.1	0.1	Miosis, blurred vision, tearing, increased salivation, weakness, nausea, vomiting, abdominal cramps, diarrhea, giddiness, confusion, loss of muscle coordination, runny nose, headache, chest tightness, difficulty breathing, pulmonary edema, muscle twitching, coma, respiratory distress, cardiac irregularities, and convulsions.	Lungs, liver, CNS, heart, ChE Inh	NA	No effects were seen in volunteers after a single oral dose of 0.84 mg/kg (11.6 mg/L) or repeated doses of 16 mg/day (3.2 mg/L) for 47 days. The fatal dose is believed to be between 350-1000 mg/kg (4.9-14 mg/L).
Maleic hydrazide 123-33-1	14	14	5	5	Tremors and muscle spasms.	CNS	NA	

Chemical CAS No.	5 L/day MEG † (mg/L)		15 L/day MEG † (mg/L)		Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
	5-day	2-week	5-day	2-week				
MCPA 94-74-6	0.14	0.14	0.05	0.05	Fatigue, weakness, loss of appetite, nausea, vomiting, diarrhea, lethargy, constricted pupils, hypotension, slurred speech, muscle twitches, random jerky movements, paralysis and convulsions; kidney and liver injury, reduced white and red blood cell counts.	CNS, kidneys, liver, blood	NA	Ingestion of 250 mg/kg (3.5 g/L) is fatal.
Methomyl 16752-77-5	0.1	0.1	0.03	0.03	Severe headache, nausea, vomiting, diarrhea, abdominal cramps, sweating, salivation, blurred vision, constricted pupils, muscle twitching, incoordination, weakness, difficulty breathing, increased heart rate; liver and kidney damage; changes in electrocardiograph patterns are possible.	CNS, CVS, liver, kidneys, ChE Inh	NA	Doses of 12-15 mg/kg (168-210 mg/L) can be fatal.
Methoxychlor 72-43-5	0.08	0.08	0.03	0.03	Muscle spasms, trembling, and convulsions; high concentrations may injure the kidney and liver.	CNS, liver, kidneys	NA	Daily doses of 2 mg/kg (28 mg/L) for 6 weeks had no adverse effects in volunteers. The fatal oral dose for humans had been estimated to be 6 g/kg (84 g/L).
Methyl tert-butyl ether 1634-04-4	33.6	33.6	11.3	11.3	Low acute toxicity by ingestion.			C carcinogen.
Methyl parathion 298-00-0	0.4	0.4	0.15	0.15	Nausea, vomiting, abdominal cramps, diarrhea, salivation, headache, weakness, giddiness, dizziness, runny nose, blurred vision, miosis, cardiac	Eyes, CNS, CVS, liver, kidneys, ChE Inh	NA	Volunteers receiving oral doses of 22 mg/day (4.4 mg/L) suffered no ill effects. Depression of red blood cell cholinesterase

Chemical CAS No.	5 L/day MEG † (mg/L) 5-day	 2-week	15 L/day MEG † (mg/L) 5-day	 2-week	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
					arrhythmias and ischemia, difficulty breathing; muscle twitch, convulsions, liver and kidney damage, coma and respiratory paralysis are possible at high concentrations.			occurred at doses of 30 mg/day (6 mg/L) which was considered to be the level of minimal toxicity. Ingestion of 50 to 200 g (10-40 g/L) has resulted in death; the minimum adult lethal dose by the oral route may be less than 1.84 g (370 mg/L).
Metolachlor 51218-45-2	3	3	1	1	Headache, nausea, vomiting, abdominal cramps, diarrhea, sweating, weakness, anemia, incoordination, CNS depression, dark urine, liver and kidney damage, jaundice, methemoglobinemia, cyanosis, hypothermia, convulsions; affect fertility.	CNS, liver, kidneys, blood	NA	C carcinogen.
Metribuzin 21087-64-9	6.3	6.3	2	2	CNS depression; thyroid, kidney and liver injury.	CNS, thyroid, kidneys, liver	NA	
Molybdenum trioxide 7439-98-7	0.03	0.03	0.009	0.009	Weight loss, diarrhea, poor muscle coordination, headaches, muscle or joint aching.	Liver, kidneys, blood	NA	
Naphthalene 91-20-3	0.74	0.74	0.25	0.25	Headache, profuse perspiration, confusion, listlessness, lethargy, muscle twitching, coma; nausea, vomiting, abdominal cramps, diarrhea; hemolytic anemia, methemoglobinemia; cataracts, liver and kidney damage.	Eyes, blood, liver, kidneys, CNS	NA	Ingestion of 1 g naphthalene (200 mg/L) caused near blindness within 9 hours. The lethal dose is about 2 g (400 mg/L).

Chemical CAS No.	5 L/day MEG † (mg/L) 5-day	 2-week	15 L/day MEG † (mg/L) 5-day	 2-week	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Nickel 7440-02-0	1	1	0.5	0.5	Soluble nickel salts may cause gastrointestinal distress, nausea, abdominal cramps, diarrhea, vomiting, giddiness, weariness, and headache; metallic nickel is generally considered not to be acutely toxic if ingested.	GI tract, CNS	NA	
Nitroguanidine 556-88-7	15	15	5	5	High concentrations may cause inactivity, incoordination, tremors, difficulty breathing, and cyanosis.	CNS	NA	
Nitrophenol p- 100-02-7	1.2	1.2	0.4	0.4	Fever, CNS depression, sweating, weakness, headache, dizziness, tinnitus, irregular pulse, hypotension, shallow respiration, cyanosis.	CNS, blood	Odor: 43.4 mg/L	
Oxamyl [Vydate] 23135-22-0	0.35	0.35	0.1	0.1	Tremors, blurred or dim vision, increased salivation, tearing, incontinence, diarrhea, abdominal cramps, nausea, vomiting, and difficulty breathing; convulsions, coma, and respiratory paralysis are possible at high concentrations; protracted malaise and weakness may persist after apparent recovery.		NA	

Chemical CAS No.	5 L/day MEG † (mg/L)		15 L/day MEG † (mg/L)		Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
	5-day	2-week	5-day	2-week				
Paraquat 1910-42-5	0.14	0.14	0.05	0.05	Abdominal cramping, nausea, vomiting, bloody diarrhea, headache, difficulty swallowing, fever, decreased blood pressure; higher concentrations can cause heart, kidney and liver injury and extensive lung damage with difficulty breathing, pulmonary fibrosis and edema; may reduce fertility in males.	Lungs, liver, kidneys, GI tract	NA	Single oral doses of 1 to 4 g (200 to 800 mg/L) have caused fatalities.
Pentachlorophenol 87-86-5	1.4	0.4	0.5	0.14	Weakness, thirst, loss of appetite, vomiting, shortness of breath, chest pain, sweating, headache, dizziness, high fever, hypotension, and gastrointestinal upset; high concentrations may cause lung, liver, and kidney damage and convulsions.	CNS, heart	Odor: 0.03 mg/L	Ingestion of 0.1 mg/kg (1.4 mg/L) caused no effects in volunteers. The minimum lethal dose was estimated to be 29 mg/kg (406 mg/L). B carcinogen.
Phenol 108-95-2	8	8	3	3	Corrosion of the mouth, throat, and stomach, pallor, nausea, vomiting, severe abdominal pain, cold sweats, cardiac arrhythmia, wide fluctuations in blood pressure, respiratory distress, reduced body temperature, circulatory collapse.	Liver, kidneys, CVS	Odor: 0.3 mg/L	Doses of about 14 mg/kg (200 mg/L) can have dangerous effects. The oral LD_{50} has been estimated to be 140 mg/kg (2 g/L). Phenol can react with the water supply disinfectant hypochlorite to produce objectionable tastes and odors.
Picloram 1918-02-01	28	28	9.4	9.4	Nausea, diarrhea, weakness, damage to the CNS.	CNS	NA	
Prometon 1610-18-0	0.2	0.2	0.07	0.07	Mild skin and eye irritant.	CNS	NA	

Chemical CAS No.	5 L/day MEG † (mg/L) 5-day	 2-week	15 L/day MEG † (mg/L) 5-day	 2-week	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Pronamide 23950-58-5	1	1	0.4	0.4	May cause cholestasis (blockage of bile flow in the liver) which can lead to liver damage.	Liver	NA	C carcinogen.
Propachlor 1918-16-7	0.7	0.7	0.24	0.24	Weakness, salivation, tremors; liver and kidney injury.	CNS, liver, kidneys	NA	
Propazine 139-40-2	1.4	1.4	0.5	0.5	Loss of appetite, depression; high concentrations may cause dizziness, cramps and difficulty breathing.	CNS, blood, liver	NA	C carcinogen.
Propham 122-42-9	7	7	2	2			NA	
RDX 121-82-4	0.14	0.14	0.05	0.05	Headache, irritability, fatigue, weakness, tremor, nausea, vomiting, dizziness, confusion, amnesia, insomnia, convulsions, liver injury.	CNS, liver	NA	C carcinogen.
Silver 7440-22-4	0.07	0.07	0.023	0.023	High concentrations may cause abdominal pain, diarrhea, vomiting, corrosion of the gastrointestinal tract, shock and convulsions.	Skin, eyes, CNS	NA	A single oral dose of 140 mg/kg (2 g/L) may be fatal.
Simazine 122-34-9	0.03	0.03	0.01	0.01	Incoordination, tremor, weakness, muscle spasms, difficulty breathing.	CNS, kidneys, liver	NA	C carcinogen.
Strontium 7440-24-6	36	36	12	12	Excess salivation, vomiting, colic, and diarrhea.	Bone	NA	
Styrene 100-42-5	30	3	10	1	Headache, fatigue, dizziness, confusion, malaise, drowsiness, weakness, unsteady gait, impaired manual dexterity, loss of concentration.	CNS	NA	C carcinogen.

Chemical CAS No.	5 L/day MEG † (mg/L)		15 L/day MEG † (mg/L)		Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
	5-day	2-week	5-day	2-week				
Sulfate 14808-79-8 ***TB MED 577**	300	300	100	100	Single doses can have laxative effects which can lead to dehydration, with symptoms of discomfort, weariness, apathy, impaired coordination, delirium.	GI tract	NA	Laxative effects occur at doses greater than 1490 mg (300 mg/L).
Sulfur mustard [HD] 505-60-2 ***TB MED 577**	0.14	-	0.047	-	Nausea, vomiting of blood, diarrhea, abdominal pain, fever, headache, cardiac arrhythmias, dizziness, malaise, loss of appetite, lethargy, convulsions, leukopenia, anemia, immunosuppression.	GI tract, CNS, blood	NA	The oral LD_{50} for humans has been estimated to be 0.7 mg/kg (9.8 mg/L). A carcinogen.
2,4,5-T [Trichlorophenoxy-acetic acid] 93-76-5	1	1	0.4	0.4	Chloracne, nausea, headache, fatigue, muscular aches and pains; may affect the developing fetus.	Skin, REPR	NA	The only symptom reported after ingestion of 5 mg/kg (70 mg/L) was a metallic taste in the mouth.
T-2 toxin 21259-20-1 ***TB MED 577**	0.026	-	0.0087	-	Nausea, vomiting, diarrhea, generalized burning erythema, mental confusion.	GI tract, CNS	NA	Nausea and vomiting can be expected to occur at a concentration of 0.05 mg/L. The most severe effects, including gastrointestinal problems, diarrhea, generalized burning erythema, and mental confusion, occur at a concentration of 0.78 mg/L.
TCDD (2,3,7,8-) 1746-01-6	1E-06	1E-07	5E-07	5E-08	Headache, nausea, vomiting, severe muscle pain, liver damage, chloracne, porphyria cutanea tarda, hair loss,	Liver, skin, kidneys, blood, REPR system	NA	Human lethal doses have been estimated to be greater than 100 ?g/kg (1.4 mg/L).

Chemical CAS No.	5 L/day MEG † (mg/L) 5-day	 2-week	15 L/day MEG † (mg/L) 5-day	 2-week	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
					hyperpigmentation, polyneuropathy, neurobehavioral effects, possible immunosuppression, thymic atrophy.			B carcinogen.
Tebuthiuron 34014-18-1	3.5	3.5	1	1	Reversible pancreatic changes.	Pancreas	NA	
Terbacil 5902-51-2	0.35	0.35	0.1	0.1	Pallor, prostration, vomiting, and rapid respiration.	Liver	NA	
Terbufos 13071-79-9	0.007	0.007	0.002	0.002	Nausea, vomiting, abdominal cramps, diarrhea, excessive salivation, headache, dizziness, weakness, excessive tearing and salivation, ocular pain, blurred vision, constricted pupils, incoordination, slurred speech, muscle twitches, mental confusion, drowsiness, difficulty breathing, cyanosis, cardiac irregularities, incontinence, convulsions, and coma.	CNS, CVS, ChE Inh	NA	
Tetrachloroethane (1,1,1,2-) 630-20-6	3	3	1	1	Weakness, fatigue, nausea, headache, incoordination; liver injury, decreased red blood cell counts, increased percent of large mononuclear cells in blood.	CNS, liver blood	NA	C carcinogen.
Tetrachloroethylene 127-18-4	2.8	2.8	0.9	0.9	Nausea, dizziness, incoordination, headache, sleepiness, liver damage.	Liver, CNS	NA	
Thallium 7440-28-0	0.01	0.01	0.003	0.003	Metallic taste in the mouth, fatigue, anxiety, irritability, gastroenteritis, diarrhea or constipation, vomiting, abdominal	Eyes, CNS, PNS, GI tract, lungs, liver, kidneys	NA	An oral dose of 3.4 mg/kg (48 mg/L) produced chest pain, vomiting, paresthesia of the hands

Chemical CAS No.	5 L/day MEG † (mg/L) 5-day	 2-week	15 L/day MEG † (mg/L) 5-day	 2-week	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
					pain, chest pain, paresthesia of the hands and feet, tremor, convulsions, pain and loss of muscle strength in the limbs, hair loss, vision loss; damage to the lungs, kidneys, and nervous system; hypertension, EKG changes and other cardiovascular effects.			and feet, and weakness; 7 mg/kg (100 mg/L) may be fatal. Symptoms of acute exposure are typically delayed hours to days.
Toluene 108-88-3	30	3	10	1	Fatigue, nausea, weakness, confusion; higher concentrations can cause headache, vomiting, diarrhea, depressed respiration, loss of muscle coordination.	CNS	Odor: 0.04 – 1 mg/L	CHID under development.
2,4,5-TP 93-72-1	0.3	0.3	0.09	0.09	Fatigue, weakness, nausea, vomiting, abdominal pain, diarrhea, muscle twitching, weakened reflexes, constricted pupils; high concentrations can produce profuse sweating, hypotension, painful neuritis, metabolic acidosis, fever, rapid heart beat, hyperventilation, and coma.	Liver, kidneys, CNS	NA	
Trichloroacetic acid 76-03-9	5.6	5.6	1.9	1.9	Gastrointestinal disturbances, acidosis, vomiting, diarrhea, and lassitude; decreased plasma lactate and glucose levels, and hypotension; high concentrations may cause CNS depression.	GI tract, liver, kidneys	NA	C carcinogen.
Trichloroacetonitrile 545-06-2	0.07	0.07	0.023	0.023			NA	

Chemical CAS No.	5 L/day MEG † (mg/L) 5-day	 2-week	15 L/day MEG † (mg/L) 5-day	 2-week	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Trichlorobenzene (1,2,4-) 120-82-1	0.2	0.2	0.06	0.06	Lethargy, incoordination, changes in liver, kidneys and adrenal glands.	Liver, kidneys, adrenal glands	NA	
Trichlorobenzene (1,3,5-) 108-70-3	0.8	0.8	0.3	0.3	Lethargy, incoordination, changes in liver, kidneys, and adrenal glands.	Liver, kidneys, adrenal glands	NA	
Trichloroethane (1,1,1-) 71-55-6	140	60	50	20	Headache, weakness, dizziness, increased reaction time, impaired judgment; high concentrations can cause severe vomiting and diarrhea, cardiac arrhythmias and liver damage.	CNS, CVS, liver	NA	Exposure to about 600 mg/kg (8.4 g/L) can cause incapacitating vomiting and diarrhea.
Trichloroethane (1,1,2-) 79-00-5	0.8	0.5	0.3	0.2	Headache, weakness, dizziness, nausea, vomiting, and diarrhea; drowsiness, loss of coordination and judgment; possible liver and kidney damage.	CNS, liver, kidneys	NA	C carcinogen.
Trichloroethylene 79-01-6	2.8	2.8	0.9	0.9	Headache, dizziness, blurred vision, fatigue, giddiness, tremor, sleepiness, nausea, vomiting, abdominal pain, cardiac arrhythmias, mild liver dysfunction; may cause birth defects.	CNS, CVS, liver, kidneys, REPR	NA	Doses of 21 to 35 g (4.2 - 7 G/L) can cause vomiting and abdominal pain followed by transient unconsciousness. probable human carcinogen. MEGs were derived from the ATSDR acute oral MRLs.
Trichloropropane (1,2,3-) 96-18-4	0.8	0.8	0.3	0.3	CNS damage, liver and kidney changes, lethargy, cardiovascular abnormalities.	CNS, liver, kidney, CVS, blood	NA	B carcinogen.
Trifluralin 1582-09-8	0.1	0.1	0.04	0.04	Liver and kidney changes, anemia, CNS depression.	CNS, liver, kidney, blood	NA	C carcinogen.

Chemical CAS No.	5 L/day MEG † (mg/L) 5-day	 2-week	15 L/day MEG † (mg/L) 5-day	 2-week	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Trinitroglycerol 55-63-0	0.007	0.007	0.002	0.002	Severe throbbing headache, nausea, hypotension, light-headedness; high exposure can cause flushing of the face and neck, vomiting, dizziness, delirium, confusion, methemoglobinemia, hallucinations, and difficulty breathing.	CVS, blood, CNS, testes	NA	Doses of 0.15 to 0.6 mg (0.03-0.12 mg/L) affect the cardiovascular system causing vasodilation and general relaxation of the smooth musculature.
Trinitrotoluene (2,4,6-) 118-96-7	0.025	0.025	0.008	0.008	Red pigmentation in the urine, abdominal pain, methemoglobinemia, anemia, ataxia, cyanosis, tremors; high concentrations may cause convulsions; liver damage, gastrointestinal tract irritation; male reproductive effects.	Liver, blood, GI tract, CNS	NA	C carcinogen.
Vinyl chloride 75-01-4	3.6	3.6	1.2	1.2	Headache, dizziness, loss of muscle coordination, inebriation, euphoria, fatigue, numbness and tingling of the extremities, drowsiness, and visual disturbances.	CNS	NA	A carcinogen.
VX 50782-69-9 ***TB MED 577**	0.015	-	0.005	-	Nausea, vomiting, diarrhea, abdominal cramps, headache, giddiness, dizziness, excessive salivation, tearing, miosis, blurred or dim vision, miosis, difficulty breathing, cardiac arrhythmias, loss of muscle coordination, muscle twitching, random jerking movements, convulsions, coma.	CNS, ChE Inh	NA	Single oral doses of 0.002 to 0.0045 mg/kg (0.028-0.063 mg/L) caused gastrointestinal effects in 5/32 volunteers; repeated doses of 0.00143 mg/kg/day (0.02 mg/L/day) in the drinking water 4 times/day for 7 days

Chemical CAS No.	5 L/day MEG † (mg/L) 5-day	 2-week	15 L/day MEG † (mg/L) 5-day	 2-week	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
								caused no effects. The human oral LD_{50} value has been estimated to be 0.0075 mg/kg (0.11 mg/L).
Xylenes 1330-20-7	60	60	20	20	Headache, weakness, dizziness, confusion, nausea, vomiting, abdominal pain, shivering, incoordination, loss of appetite, tremors, disturbed vision, salivation, and difficulty breathing; liver and kidney damage, and cardiac arrhythmias are possible.	CNS, liver, kidneys, blood, GI tract	Odor: 0.3 – 1.0 mg/L	The lowest oral lethal dose was reported to be 50 mg/kg (700 mg/L).
Zinc chloride [measured as Zinc] 7646-85-7	8	8	3	3	Severe stomach irritation, nausea, vomiting, and diarrhea.	GI tract	NA	

Footnotes on next page.

FOOTNOTES FOR TABLE D-1 – SHORT-TERM WATER-MEG VALUES

† In temperate conditions, the estimated rate of consumption is 5 liters/day. In arid regions, the estimated rate of consumption is 15 liters/day.

‡ The sources for odor and taste thresholds in water were the U.S. Environmental Protection Agency *Health Advisory* for individual chemicals and the National Library of Medicine's Hazardous Substance Database (HSDB).

§ The notes column shows estimated oral doses that can cause the toxic effects indicated when available. The reported doses were converted into mg/L concentrations in water (shown in parentheses) for 5 L/day consumption rates. Divide by 3 to convert to 15 L/day consumption rates. Estimated lethal doses and approximate toxic effect levels were obtained from the TOMES database software system, from Gosselin et al. (1976), from Hayes, *Pesticides Studied in Man* and from the EPA Health Advisory Source documents.

***TB MED 577** -- These values were taken from *TB MED 577, they are STANDARDS and should not be exceeded.
*Department of the Army (Da). *Sanitary Control And Surveillance Of Field Water Supplies*, Final Draft Technical Bulletin, Medical (TBMED) 577, May 1999.

Other values obtained from following hierarchy sources [USEPA HA-ADJ ≥ ATSDR MRL-ADJ> USEPA RFD–ADJ] unless otherwise noted (see RD 230 for more details):

ATSDR primary sources :
- Agency for Toxic Substances and Disease Registry (ATSDR), 1996. *Toxicological Profiles*. Prepared by Clement International Corporation under Contract No. 205-88-0608. Prepared for U.S. Department of Health and Human Services, Public Health Service, Washington, D.C.

US EPA primary sources:
-U.S. Environmental Protection Agency (USEPA), 1996a. 822-R-96-001, *Drinking Water Regulations and Health Advisories*, Office of Water, United States Environmental Protection Agency, October 1996.U.S. Environmental Protection Agency (USEPA), 1996b. Soil Screening Guidance: User's Guide. Office of Solid Waste and Emergency Response. Washington D.C

-U.S. Environmental Protection Agency (USEPA), 1999a. *Integrated Risk Information System (IRIS)*. Environmental Criteria and Assessment Office, Office of Health and Environmental Assessment, Cincinnati, OH.

CHID – Chemical Hazard Information for Deployments. Summarized information in fact sheet format is under development for notated chemicals.
EEG – electrocardiogram
NA – Not Available

Target organ/systems, carcinogenicity, and units information next page……

TABLE 2-4-1. TARGET ORGANS

TARGET ORGANS	
Eyes	Brain
Skin	Heart
Blood	Pancreas
Bladder	Adrenal Glands
Thyroid	Lungs
Bone	Liver
Fetus	Kidneys
Spleen	

TABLE 2-4-2. TARGET SYSTEMS

TARGET SYSTEMS	
CNS – Central Nervous System	CVS – Cardiovascular System
PNS – Peripheral Nervous System	ChE Inh – Cholinesterase Inhibitor
GI tract – Gastrointestinal Tract	UT – Urogenital Tract
RS – Respiratory System	CRC – Circulatory System
LRS – Lower Respiratory System	IMM – Immune System
URS – Upper Respiratory System	REPR – Reproductive System
ENDO – Endocrine System	HEM – Hemopoietic System
LYMP – Lymphatic System	

Units used:

g – gram
mg = milligram
L = Liter
mL = milliliter
mg/kg/day == milligram chemical per kilogram body weight (ingested) per day

µg/kg = micrograms per kilogram = ppb = parts per billion
mg/L = milligram per liter = ppm = part per million

Cancer Class Categories:

The scheme used by the USEPA for categorizing chemicals according to their carcinogenic potential is as follows (see Section 2.4.3):
Group A: Human carcinogen
Group B: Probable human carcinogen:
Group B1 - Limited evidence in epidemiological studies
Group B2 - Sufficient evidence from animal studies
Group C: Possible human carcinogen
Group D: Not classifiable
Group E: No evidence of carcinogenicity

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TABLE D-2. LONG-TERM, WATER MILITARY EXPOSURE GUIDELINES (1 YEAR DEPLOYMENT)

Chemical CAS No.	5 L/day † 1-yr MEG (mg/L)	15 L/day † 1-yr MEG (mg/L)	Cancer Group	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Acenaphthene 83-32-9	8.4	2.8	NA	May cause slight changes in the liver.	Liver	NA	This chemical is a PAH. MEGs are derived using a relative potency (toxicity equivalency factor for carcinogencity as well as a relative comparison to Total Petroleum Hydrocarbon (TPH) toxicity estimates. Se section 3.3.5.10 in RD230)
Acenaphthylene 208-96-8	4.2	1.4	D	As with other polycyclic aromatic hydrocarbons (PAHs), toxicity following short-term exposure is minimal. Long-term exposure to PAHs can produce a variety of non-cancer effects including irritation of the eyes and photosensitivity, mild liver or kidney damage, anemia and other changes in the blood cells.	Liver, kidneys, blood, IMM	NA	See above (Acenaphthene)
Acetone 67-46-1	14	4.7	D	Headache, dizziness, CNS depression.	CNS	Odor: 20 mg/L	
Alachlor 15972-60-8	0.14	0.05	B2	May damage the liver, kidney and spleen; cancer.	Liver, kidneys, spleen	NA	
Aldrin 309-00-2	0.0004	0.00013	B2	Nausea, vomiting, diarrhea, hyperexcitability, tremors, limb jerks, convulsions, and ventricular fibrillation; reversible kidney and liver injury; cancer.	CNS, liver, kidneys	Odor: 0.017 mg/L	Ingestion of 25.6 mg/kg (360 mg/L) can produce convulsions; a single oral dose of 5 g (1 g/L is lethal.

Chemical CAS No.	5 L/day † 1-yr MEG (mg/L)	15 L/day † 1-yr MEG (mg/L)	Cancer Group	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Anthracene 120-12-7	140	47	D	Contact may make the skin more susceptible to the effects of sunlight. Long-term exposure to PAHs can produce a variety of non-cancer effects including irritation of the eyes and photosensitivity, mild liver or kidney damage, anemia and other changes in the blood cells.	Liver, kidneys, blood, IMM, skin	NA	This chemical is a PAH. MEGs are derived using a relative potency (toxicity equivalency factor for carcinogencity as well as a relative comparison to Total Petroleum Hydrocarbon (TPH) toxity estimates. Se section 3.3.5.10 in RD230)
Aroclor-1016 12674-11-2	0.001	0.0003	NA	Nausea, vomiting, liver damage, facial edema, abdominal pain, weight loss, diarrhea; headache, dizziness, depression, weakness, transient visual disturbances; chloracne; birth defects, peripheral nerve damage. Cumulative toxicity; liver and kidney damage.	CNS, liver, kidneys	NA	Minimal oral dose expected to cause symptoms is 500 mg (7 mg/kg).
Aroclor-1254 11097-69-1	0.0007	0.0002	NA	Nausea, vomiting, liver damage, facial edema, abdominal pain, weight loss, diarrhea; headache, dizziness, depression, weakness, transient visual disturbances; chloracne; birth defects, peripheral nerve damage. Cumulative toxicity, liver and kidney damage.	CNS, liver, kidneys	NA	Minimal oral dose expected to cause symptoms is 500 mg (7 mg/kg).

Chemical CAS No.	5 L/day † 1-yr MEG (mg/L)	15 L/day † 1-yr MEG (mg/L)	Cancer Group	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Arsenic 7440-38-1 ***TB MED 577**	0.06	0.02	A	Facial swelling, vomiting, loss of appetite, abdominal pain; diarrhea, shock, muscle cramps, headache, chill, cardiac abnormalities, decreased white blood cell count, and enlargement of liver; delayed effects include sensory and motor peripheral polyneuropathies. Hyperpigmentation of the skin (especially on the palms of the hands and soles of the feet), anemia, weakness, incoordination, mental confusion, cirrhosis of the liver, hair loss, and nail changes; cancer.	Liver, kidneys, blood, CNS, GI tract, IMM	NA	The risk of developing symptoms of acute toxicity increases as the concentration in drinking water increases above 0.3 mg/L. The risk of severe toxic effects and fatalities increases as concentrations rise above 14 mg/L. CHID under development.
Benzene 71-43-2	0.042	0.014	A	Vomiting, loss of coordination, light-headedness, headache, anemia, shallow/rapid pulse, loss of concentration, delirium, chemical pneumonitis, dizziness, pallor, flushing, weakness, and breathlessness; high concentrations may cause convulsions, coma, or irregular heart beat. Fatigue, headache, dizziness, nausea, loss of appetite, weakness, nosebleeds, pallor, and bleeding gums; bone marrow damage; immunosuppression;	Eyes, skin, RS, blood, CNS, IMM	Odor: 2.0 mg/L Taste: 0.5 – 4.5 mg/L	The LD_{LO} has been estimated to equal 50 mg/kg. CHID under development.

Chemical CAS No.	5 L/day † 1-yr MEG (mg/L)	15 L/day † 1-yr MEG (mg/L)	Cancer Group	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Benzo(a)anthracene 56-55-3	0.14	0.05	B2	As with other PAHs, toxicity following short-term exposure is minimal. Long-term exposure to PAHs can produce a variety of non-cancer effects including irritation of the eyes and photosensitivity, mild liver or kidney damage, anemia and other changes in the blood cells. Long-term exposure may cause cancer.	Liver, kidneys, blood, IMM	NA	This chemical is a PAH. MEGs are derived using a relative potency (toxicity equivalency factor for carcinogencity as well as a relative comparison to Total Petroleum Hydrocarbon (TPH) toxity estimates. Se section 3.3.5.10 in RD230)
Benzo(a)pyrene 50-32-8	0.014	0.005	B2	Toxicity from short-term exposure is low. Long-term exposure may cause depression of the immune system; mild liver or kidney damage; changes in the blood composition such as aplastic anemia and pancytopenia; and cancer. Effects on the developing fetus have been observed in laboratory animals.	Liver, kidneys, blood, IMM	NA	See above (Benzo(a)anthracene)
Benzo(b)fluoranthene 205-99-2	0.14	0.05	B2	As with other polycyclic aromatic hydrocarbons (PAHs), toxicity following short-term exposure is minimal. Long-term exposure to PAHs can produce a variety of non-cancer effects including irritation of the eyes and photosensitivity, mild liver or kidney damage, anemia and other changes in the blood cells. Long-term exposure may cause cancer.	Liver, kidneys, blood, IMM	NA	See above (Benzo(a)anthracene)

Chemical CAS No.	5 L/day † 1-yr MEG (mg/L)	15 L/day † 1-yr MEG (mg/L)	Cancer Group	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Benzo(k)fluoranthene 207-0809	1.4	0.5	B2	Toxicity following short-term exposures is minimal.. Long-term exposure to PAHs can produce a variety of non-cancer effects including irritation of the eyes and photosensitivity, mild liver or kidney damage, anemia and other changes in the blood cells. Long-term exposure may cause cancer.	Liver, kidneys, blood, IMM	NA	See above (Benzo(a)anthracene)
Beryllium 7440-41-7	0.02	0.007	B2	Low acute toxicity by ingestion. Rickets (fragile or weakened bones); cancer.	Bone	NA	
Bis(2-ethylhexyl)-phthalate 117-81-7	0.28	0.056	B2	Liver damage, possible teratogenic and carcinogenic effects.	Skin, liver, REPR, CNS, GI tract	NA	Chronic exposure may cause liver tumors.
Boron 7440-42-8	1.7	0.4	D	Vomiting, abdominal pain, diarrhea; headache, tremors, restlessness, weakness, convulsions; may affect the liver, and may cause skin rash and desquamation.	CNS, skin, kidneys	NA	Prolonged ingestion/skin absorption may result in anorexia, weight loss, anemia. Long term USEPA and State standards range 0.6 – 1.0 mg/L
Bromodichloromethane 74-97-5	0.3	0.1	B	Loss of appetite, nausea, vomiting, abdominal pain, severe headache, confusion, dizziness, memory impairment, weakness, tremors and convulsions; elevated carboxyhemoglobin; kidney, liver tumors in animals.	CNS, skin, kidneys	NA	Long term USEPA and State standards range 0.6 – 1.0 mg/L
sec-Butylbenzene 135-98-8	0.15	0.05	NA	Skin irritation, CNS depression, incoordination, nausea, general anesthetic effects.	Skin, CNS	NA	

Chemical CAS No.	5 L/day † 1-yr MEG (mg/L)	15 L/day † 1-yr MEG (mg/L)	Cancer Group	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Cadmium 7440-43-9	0.007	0.002	NA	Nausea, vomiting, diarrhea, muscle cramps, salivation, sensory disturbances, liver injury, convulsions, shock, and renal failure. Pain resulting from softening or decalcification of the bones, osteoporosis, irreversible kidney disease, anemia.	Kidneys, liver	NA	Ingestion of 3 mg (0.6 mg/L) may cause vomiting; 30 mg (6 mg/L) of soluble cadmium salts can produce severe toxic symptoms; 350 mg (70 mg/L) may be fatal.
Carbon disulfide 75-15-0	0.14	0.05	NA	Dizziness, headache, nausea, vomiting, diarrhea, fatigue, palpitations and weakness; high concentrations may cause psychosis, tremor, delirium, coma, muscle spasm, convulsions, difficulty breathing, and liver damage. Decreased fertility in males and females.	CNS, PNS, liver, REPR s	NA	
Chlordane 57-74-9	0.008	0.003	B2	Nausea, vomiting, diarrhea, headache, excitability, confusion, weakness, incoordination; high concentrations may cause delirium, muscle spasms, convulsions or seizures, coma, pulmonary edema, and difficulty breathing. Kidney and liver degeneration; blood dyscrasias; cancer.	CNS, liver, kidneys	NA	Ingestion of 28 to 56 mg/kg (390-780 mg/L) may cause severe effects such as convulsions. The fatal human dose lies between 6 and 60 g (1 and 10 g/L). The onset of symptoms occurs 45 minutes to several hours after ingestion.

Chemical CAS No.	5 L/day † 1-yr MEG (mg/L)	15 L/day † 1-yr MEG (mg/L)	Cancer Group	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Chloride 16887-00-6 ***TB MED 577**	600	600	NA	Reduced water consumption due to high chloride concentrations can lead to dehydration, with symptoms including weariness, apathy, impaired coordination, delirium, heat stroke.	None (palatability issue; see notes)	NA	Exposure guidelines are based on palatability; at 600 mg//L, 2% of the military population might refuse to drink water and may suffer dehydration; at 1,000 mg/L, 10% would be at risk of dehydration.
Chloroform 67-66-3	1.4	0.5	B2	Dizziness, mental dullness, headache, nausea, confusion, fatigue, narcosis, liver and kidney damage/cancer; renal necrosis.	Kidneys, CNS, bladder, fetus	NA	USEPA long-term standard (MCL) = 0.1 mg/L States range 0.6 – 0.005 mg/L.
Chloromethane (Methyl chloride) 74-87-3	0.5	0.17	C	Headache, drowsiness, giddiness, dizziness, confusion, incoordination, vomiting, abdominal pain, diarrhea, breathing difficulties; high concentrations may cause unconsciousness, convulsions, coma, visual disturbances, and may damage the kidneys, liver, or blood; cancer.	CNS, liver, kidneys, REPR	NA	Symptoms of chloromethane exposure may be delayed in onset.
Chlorothalonil 1897-45-6	0.2	0.07	B2	Vomiting, rapid breathing, GI irritation, weakness, and sedation. Cumulative toxicity; incoordination, rapid breathing, hematuria (blood in the urine), nosebleed, delayed hypersensitivity; cancer.	CNS, GI tract, UT	NA	
Chromium (total) 7440-47-3	0.3	0.1	D	The toxicity of chromium has been attributed primarily to hexavalent chromium compounds.	Kidneys, liver	NA	The MEGs for total chromium were based on studies with hexavalent chromium [Cr(VI)] and reflect the toxicity of Cr(VI) compounds.

Chemical CAS No.	5 L/day † 1-yr MEG (mg/L)	15 L/day † 1-yr MEG (mg/L)	Cancer Group	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Chromium III 16065-83-1	21	7	NA	Hexavalent chromium compounds are more toxic than trivalent chromium compounds.	Kidneys, liver	NA	
Chromium VI 18540-29-9	0.3	0.1	NA	Ingestion of hexavalent chromium compounds may cause GI irritation, epigastric pain, nausea, vomiting, diarrhea, liver and kidney damage, internal bleeding, circulatory collapse, unconsciousness, and death. Reduced fertility and birth defects are possible.	Kidneys, liver	NA	Doses of 0.5 – 1.5 g (7-21 mg/kg) $K_2Cr_2O_7$ have been fatal.
Chrysene 218-01-9	4.2	1.4	B2	As with other PAHs, toxicity following short-term exposure is minimal. Long-term exposure to PAHs can produce a variety of non-cancer effects including irritation of the eyes and photosensitivity, mild liver or kidney damage, anemia and other changes in the blood cells, and immunosuppression. Long-term exposure may cause cancer.	Liver, kidneys, blood, IMM	NA	This chemical is a PAH. MEGs are derived using a relative potency (toxicity equivalency factor for carcinogencity as well as a relative comparison to Total Petroleum Hydrocarbon (TPH) toxicity estimates. Se section 3.3.5.10 in RD230)
Copper (II) (Salts, Oxide) 1317-38-0	1.0	1.0	D	Ingestion at high concentrations can produce vomiting, diarrhea, nausea, abdominal pain and a metallic taste in the mouth. Potential kidney and liver injury after chronic exposures.	GI tract, liver, kidneys	NA	The major soluble salts e.g., copper (II) sulfate, copper II chloride) are of most toxic concern. Elemental copper (7440-50-8) is an essential element and therefore *deficiencies* can result in adverse health effects. USEPA and States standards range 1.0 – 1.3 mg/L

Chemical CAS No.	5 L/day † 1-yr MEG (mg/L)	15 L/day † 1-yr MEG (mg/L)	Cancer Group	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Cumene 98-82-8	1.4	0.47	D	CNS effects, skin irritation.	CNS, Skin	NA	
Cyanide 57-12-5 ***TB MED 577**	6	2	NA	Headache, breathlessness, weakness, palpitation, nausea, vomiting, giddiness, tremor, rapid heart beat, dizziness, confusion, anxiety, agitation, confusion, cardiac arrhythmias, seizures, stupor, and coma. CNS effects (insomnia, memory loss, tremors); degeneration of spinal cord and optic nerve; enlargement of the thyroid gland; reduced fertility and birth defects are possible.	CNS, RS, CVS, liver, kidneys	NA	Concentrations between 12 and 24 mg/L may cause changes in blood chemistry without clinical effects. Severe but reversible symptoms may occur at concentrations of 24 to 48 mg/L; concentrations higher than 48 mg/L cause life-threatening toxicity.
2,4-D (2,4-Dichlorophenoxy-acetic acid) 94-75-7	0.14	0.05	D	Nervous system damage, vomiting, diarrhea, lethargy, incoordination, weakness, paralysis, stupor, miosis, stiffness in the extremities, muscle spasms, lowered blood pressure, convulsions; transient liver and kidney damage; may cause birth defects and reduced fertility. Cumulative toxicity.	CNS, liver, kidneys	NA	Ingestion of a single dose of 5 mg/kg (70 mg/L) and repeated doses of 7 mg/kg/day (98 mg/L) for 21 days caused no effects. The single oral lethal dose has been estimated to be 355 mg/kg (5 g/L). Survival following a dose of about 110 mg/kg (1.5 g/L) has been reported.

Chemical CAS No.	5 L/day † 1-yr MEG (mg/L)	15 L/day † 1-yr MEG (mg/L)	Cancer Group	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
p,p'-DDT 50-29-3	0.007	0.002	NA	Vomiting, tingling of lips, tongue, and face; malaise, headache, sore throat, fatigue, tremors; apprehension, ataxia, confusion, convulsions, coma and partial paralysis. Estrogenic effects; may reduce fertility.	Eyes, skin, CNS, kidneys, liver, PNS	NA	
Diazinon 333-41-5	0.007	0.002	E	Nausea, vomiting, diarrhea, headache, dizziness, weakness, excessive tearing and salivation, ocular pain, blurring/dimness of vision, miosis, loss of muscle coordination, slurred speech, muscle twitching, disorientation, drowsiness, difficulty breathing, hypertension, hypotension, cardiac arrhythmias, random jerky movements, incontinence, convulsions, and coma. Cumulative toxicity; loss of visual acuity.	Eyes, RS, CNS, CVS, blood, ChE Inh	NA	
Dibromochloromethane 594-18-3	2.8	0.9	C	CNS functional disturbances including sedation and anesthesia; reversible liver and kidney injury.	CNS, liver, kidneys	NA	USEPA and State standards range 0.8 – 0.0002 mg/L.
Dibromochloropropane 96-12-8	0.03	0.009	B2	GI distress; may damage the kidney, liver, and testes. Kidney and liver damage, atrophy of the testes and sterility in males; cancer.	Liver, kidneys, spleen, REPR, GI tract, CNS	Odor: 0.01 – 3.1 mg/L	

Chemical CAS No.	5 L/day † 1-yr MEG (mg/L)	15 L/day † 1-yr MEG (mg/L)	Cancer Group	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Dieldrin 60-57-1	0.0007	0.0002	B2	Early signs of toxicity are headache, dizziness, nausea, vomiting, malaise, sweating, tremors, limb jerks, EEG changes, convulsions, and coma; secondary effects include hypertension, cardiac arrhythmias, and fever; sleep, memory, behavioral disturbances, headache, and convulsions may persist for months following exposure. Cumulative toxicity; fainting, muscle spasms, tremors, weight loss, reduced psychomotor skills, hemolytic anemia; reproductive effects may occur; cancer	CNS	Odor 0.04 mg/L	No effects were seen in volunteers given doses of 0.21 mg (0.04 mg/L). Serious effects may occur at a dose of 10 mg/kg (140 mg/L); 29 mg/kg (420 mg/L) caused profuse vomiting or prolonged convulsions; the acute mean lethal dose for humans has been estimated to lie between 230 and 70 mg/kg (280 to 980 g/L). Oral doses of dieldrin ranging from 10 to 211 ?g over a period of 10 months had no adverse effects in volunteers.
Dinitrobenzene (1,3-) 99-65-0	0.06	0.02	D	Methemoglobinemia associated with headache, irritability, dizziness, weakness, nausea, lethargy, shortness of breath, liver damage. May cause reduced fertility and birth defects.	Blood, liver, CNS, CVS	NA	The lethal dose has been estimated to lie between 5 and 50 mg/kg (70 and 700 mg/L).
Dinoseb 88-58-7	0.014	0.005	D	Nausea, vomiting, abdominal pain, marked thirst, fatigue, sweating, facial flushing, rapid heart beat, fever, weight loss, respiratory distress, cyanosis, restlessness, anxiety, muscle cramps, excitement, convulsions, and coma. Liver or kidney damage; cataracts; may affect fertility.	CNS, REPR	NA	

Chemical CAS No.	5 L/day † 1-yr MEG (mg/L)	15 L/day † 1-yr MEG (mg/L)	Cancer Group	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Disulfoton 298-04-4	0.004	0.001	E	Headache, loss of appetite, nausea, vomiting, abdominal cramps, diarrhea, weakness, dizziness, confusion, slurred speech, salivation, tearing, profuse sweating, shortness of breath, tightness of the chest, changes in heart rate, cyanosis, miosis, blurred vision, runny nose, slow pulse, muscle twitching, tremors, muscle cramps, incoordination, convulsions, coma, and shock. Decreased visual acuity, liver injury, altered tendon reflexes.	Eyes, RS, CNS, CVS, ChE Inh	NA	Oral doses of 0.75 mg/d (0.15 mg/L) for 30 days produced no significant effects in volunteers. The human LD_{50} has been estimated to be 5 mg/kg (70 mg/L).
Endrin 72-20-8	0.006	0.002	D	Headache, dizziness, nausea, vomiting, hypersalivation, insomnia, lethargy, weakness, agitation and confusion; high concentrations may cause convulsions, stupor, tremors, and coma; headache, dizziness, sleepiness, weakness, and loss of appetite may persist for 2 to 4 weeks.	CNS	NA	Convulsions may be induced in humans by doses of 0.2 to 0.25 mg/kg (2.8 to 3.5 mg/L); a dose of 1 mg/kg (14 mg/L) can induce repeated seizures.
Ethyl benzene 100-41-4	1.4	0.5	D	Headache, nausea, weakness, dizziness, sleepiness, fatigue, loss of coordination, and coma.	CNS	Odor: 0.062 mg/L Taste: 0.025 mg/L	This chemical is a PAH. MEGs are derived using a relative potency (toxicity equivalency factor for carcinogencity as well as a relative comparison to Total Petroleum Hydrocarbon (TPH) toxicity estimates. Se section 3.3.5.10 in RD230)
Ethylene dibromide 106-93-4	0.0012	0.0004	B2	Liver and kidney damage, vomiting, excitement and other CNS effects; may affect fertility in males; cancer.	CNS, liver, kidneys, REPR	NA	A single oral dose of 65 mg/kg (900 mg/L) may be lethal.

Chemical CAS No.	5 L/day † 1-yr MEG (mg/L)	15 L/day † 1-yr MEG (mg/L)	Cancer Group	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Fenamiphos 22224-92-6	0.007	0.002	D	Nausea, vomiting, abdominal cramps, diarrhea, salivation, headache, dizziness, weakness, runny nose, blurred vision, constricted pupils, incoordination, slurred speech muscle twitches, random jerky movements, mental confusion, disorientation, drowsiness, difficulty breathing, cardiac irregularities, incontinence, convulsions, and coma. Cumulative toxicity.	CNS, CVS, ChE Inh	NA	
Fluoranthene 206-44-0	5.6	1.9	D	Fluoranthene can irritate the eyes. Contact may make the skin more susceptible to the effects of sunlight. Long-term exposure to PAHs can produce a variety of non-cancer effects including irritation of the eyes and photosensitivity, mild liver or kidney damage, anemia and other changes in the blood cells, and immunosuppression	Liver, kidneys, blood, IMM	NA	(This chemical is a PAH. MEGs are derived using a relative potency (toxicity equivalency factor for carcinogencity as well as a relative comparison to Total Petroleum Hydrocarbon (TPH) toxicity estimates. Se section 3.3.5.10 in RD230)
Fluorene 86-73-7	5.6	1.9	D	Skin or eye irritation.	Skin, eyes	NA	See above (Fluoranthene)

Chemical CAS No.	5 L/day † 1-yr MEG (mg/L)	15 L/day † 1-yr MEG (mg/L)	Cancer Group	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Fonofos 944-22-9	0.03	0.01	D	Loss of appetite, nausea, vomiting, abdominal cramps, diarrhea, headache, dizziness, weakness, confusion, blurred vision, constricted pupils, slurred speech, profuse sweating, salivation, and runny nose; cardiac irregularities, difficulty breathing, muscle twitching, paralysis, convulsions, coma, or respiratory arrest may occur. Nervous behavior, tremors, liver damage, GI effects, increased nasal, salivary and lacrimal secretions.	CNS, CVS, ChE Inh	NA	
Heptachlor 76-44-8	0.007	0.002	B2	Nausea, vomiting, diarrhea, kidney and liver damage; hyperexcitability, tremors, convulsions, and paralysis. Cumulative toxicity; blood dyscrasias. Reduced fertility has been observed in animal studies; cancer.	CNS, liver	NA	A dose of 1 to 3 g (200-600 mg/L) has been estimated to cause serious symptoms in humans, especially liver impairment.
Heptachlor epoxide 1024-57-3	0.0002	0.00006	B2	Apprehension, agitation, muscle twitching and spasms, tremor, incoordination, vomiting, GI upset, abdominal pain; convulsions; kidney injury and liver damage; cancer.	CNS, liver	NA	
Hexachlorobenzene 118-74-1	0.004	0.0013	B2	Headache, nausea, cyanosis, muscle spasm, convulsions, liver injury, birth defects. Porphyria cutanea tarda, enlargement of the thyroid and lymph nodes, reduced bone density, skin photosensitization, liver, kidney, and lung damage.	CNS, blood, liver, kidneys	NA	

Chemical CAS No.	5 L/day † 1-yr MEG (mg/L)	15 L/day † 1-yr MEG (mg/L)	Cancer Group	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Lead compounds No specified CAS. (measured as Total Lead)	0.015	0.015	--	Anxiety, irritability, insomnia, lack of appetite, anemia, headache, muscle weakness, restlessness, reproductive effects in developing fetus are pronounced. Possible kidney and reproductive effects after longer chronic exposures.	CNS, fetus	NA	Primary health impacts are to children/ developing fetus. But high concentrations and/or long exposures can result in health impacts to adults. MEGs were selected from general information for lead ions and compounds, including statements in the literature referenced to lead compounds, lead salts, etc. Some lead compounds (e.g. Tetra ethyl lead) have there own unique – and potent – toxicity. This MEG should be used when assessing Total Lead analytical results. CHID under development.
Lindane 58-89-9 ***TB MED 577**	0.6	0.2	C	Irritability, restlessness, insomnia, anxiety, dizziness, malaise, headache, nausea, fever, cyanosis, vomiting, and loss of muscle coordination; higher exposure can cause muscle spasms, seizures, and convulsions. Liver and kidney damage; may affect fertility; cancer.	CNS, REPR	NA	Increasing susceptibility to nervous system changes may occur at concentrations between 0.6 and 3.5 mg/L. Signs of poisoning begin to develop at 3.5 mg/L. The mean lethal dose is approximately 400 mg/kg (5.6 g/L).

Chemical CAS No.	5 L/day † 1-yr MEG (mg/L)	15 L/day † 1-yr MEG (mg/L)	Cancer Group	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Magnesium 7439-95-4 ***TB MED 577**	100	30	NA	Laxative effects that can lead to dehydration, with symptoms of discomfort, weariness, apathy, impaired coordination, delirium, and heat stroke.	GI tract	NA	Laxative effects occur at doses greater than 480 mg (96 mg/L).
Malathion 121-75-5	0.3	0.1	D	Miosis, blurred vision, tearing, increased salivation, weakness, nausea, vomiting, abdominal cramps, diarrhea, giddiness, confusion, loss of muscle coordination, runny nose, headache, chest tightness, difficulty breathing, pulmonary edema, muscle twitching, coma, respiratory distress, cardiac irregularities, and convulsions. Chronic exposure can cause fatigue, visual disturbances, headache, nausea, abdominal pain, and twitching; kidney and liver damage; may affect fertility.	Lungs, liver, CNS, CVS, ChE Inh	NA	No effects were seen in volunteers after a single oral dose of 0.84 mg/kg (11.6 mg/L) or repeated doses of 16 mg/day (3.2 mg/L) for 47 days. The fatal dose is believed to be between 350 – 1000 mg/kg (4.9 – 14 mg/L).
Mercury (inorganic) 7439-97-6	0.002	0.0007	D	Tremors, peripheral neuropathy, fatigue, memory loss, personality changes, kidney damage, cough, chest pain, difficulty breathing, liver damage, diarrhea, nausea, vomiting. Reduced visual acuity, tremor, ataxia, nerve fiber degeneration, loss of taste, smell, change in motor function, loss of higher mental function, irritability, headache, fatigue, weakness, loss of memory, depression, insomnia, apathy, hallucinations, seizures, mania; birth defects, kidney damage, dementia.	CNS	NA	

Chemical CAS No.	5 L/day † 1-yr MEG (mg/L)	15 L/day † 1-yr MEG (mg/L)	Cancer Group	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Mercury (Methyl) 22967-92-6	0.0042	0.0014	NA	Paresthesia, impaired hearing, taste and small; slurred speech, unsteady gait, muscle weakness, irritability, memory loss, depression, insomnia, ataxia, loss of visual acuity, tremors, confusion, hallucinations, excitement, loss of consciousness; nerve degeneration. Reproductive effects are possible.	CNS, kidneys	NA	Single oral doses of 10-60 mg/kg have been fatal.
Methyl ethyl ketone 78-93-3	8.4	2.8	D	Headache, dizziness, vomiting.	CNS, Skin	Taste: 0.05 mg/L	
Methyl parathion 298-00-0	0.04	0.013	D	Nausea, vomiting, abdominal cramps, diarrhea, salivation, headache, weakness, giddiness, dizziness, runny nose, blurred vision, miosis, cardiac arrhythmias and ischemia, difficulty breathing; muscle twitch, convulsions, liver and kidney damage, coma and respiratory paralysis are possible at high concentrations. Cumulative toxicity.	Eyes, CNS, CVS, liver, kidneys, ChE Inh	NA	Volunteers receiving oral doses of 22 mg/day (4.4 mg/L) suffered no ill effects. Depression of red blood cell cholinesterase occurred at doses of 30 mg/day (6 mg/L) which was considered to be the level of minimal toxicity. Ingestion of 50 to 200g (10-40 g/L) has resulted in death; the minimum adult lethal dose by the oral route may be less than 1.84 gm (370 mg/L).
Molybdenum 7439-98-7	0.07	0.02	NA	Weight loss, diarrhea, poor muscle coordination, headaches, muscle or joint aching. Changes in liver function, gout, anemia.	Liver, kidneys, blood	NA	

Chemical CAS No.	5 L/day † 1-yr MEG (mg/L)	15 L/day † 1-yr MEG (mg/L)	Cancer Group	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Naphthalene 91-20-3	0.5	1.7	D	Headache, profuse perspiration, confusion, listlessness, lethargy, muscle twitching, coma; nausea, vomiting, abdominal cramps, diarrhea; hemolytic anemia, methemoglobinemia; cataracts, liver and kidney damage.	Eyes, blood , liver, kidneys, CNS	NA	This chemical is a PAH. MEGs are derived using a relative potency (toxicity equivalency factor for carcinogencity as well as a relative comparison to Total Petroleum Hydrocarbon (TPH) toxicity estimates. Se section 3.3.5.10 in RD230)
Oxamyl (Vydate) 23135-22-0	0.35	0.1	E	Tremors, blurred or dim vision, increased salivation, tearing, incontinence, diarrhea, abdominal cramps, nausea, vomiting, and difficulty breathing; convulsions, coma, and respiratory paralysis are possible at high concentration; protected malaise and weakness may persist after apparent recovery.	ChE Inh	NA	
Paraquat 1910-42-5	0.06	0.02	E	Abdominal cramping, nausea, vomiting, bloody diarrhea, headache, difficulty swallowing, fever, decreased blood pressure; higher concentrations can cause heart, kidney and liver injury and extensive lung damage with difficulty breathing, pulmonary fibrosis and edema; may reduce fertility in males. Edema, interstitial bleeding; lung, kidney, and liver damage.	Lung, liver, kidneys, GI tract	NA	Single oral doses of 1 to 4 g (200 to 800 mg/L) have caused fatalities.

Chemical CAS No.	5 L/day † 1-yr MEG (mg/L)	15 L/day † 1-yr MEG (mg/L)	Cancer Group	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Phenanthrene 85-01-8	4.2	1.4	D	Contact may make the skin more susceptible to the effects of sunlight (photosensitization). As with other polycyclic aromatic hydrocarbons (PAHs), toxicity following short-term exposure is low. Long-term exposure to PAHs can produce a variety of non-cancer effects including irritation of the eyes and photosensitivity, mild liver or kidney damage, anemia and other changes in the blood cells, and immunosuppression.	Liver, kidneys, blood, IMM, skin	NA	This chemical is a PAH. MEGs are derived using a relative potency (toxicity equivalency factor for carcinogencity as well as a relative comparison to Total Petroleum Hydrocarbon (TPH) toxicity estimates. Se section 3.3.5.10 in RD230)
n-Propylbenzene 103-65-1	0.15	0.05	D	Irritation of throat and skin, CNS depression, incoordination, nausea, general anesthetic effects.	CNS, Skin	NA	
Pyrene 129-00-0	4.2	1.4	D	Pyrene is irritating to exposed skin and eyes. Contact may make the skin more susceptible to the effects of sunlight. As with other polycyclic aromatic hydrocarbons (PAHs), toxicity following short-term exposure is low. Long-term exposure to PAHs can produce a variety of non-cancer effects including irritation of the eyes and photosensitivity, mild liver or kidney damage, anemia and other changes in the blood cells, and immunosuppression.	Liver, kidneys, blood, IMM, skin	NA	See Note for Phenanthrene
Simazine 122-34-9	0.07	0.02	C	Incoordination, tremor, weakness, muscle spasms, difficulty breathing; cancer	CNS, kidneys, liver	NA	

Chemical CAS No.	5 L/day † 1-yr MEG (mg/L)	15 L/day † 1-yr MEG (mg/L)	Cancer Group	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Strontium 7440-24-6	8.4	2.8	NA	Skin irritation, altered heart function, bone abnormalities.	Bone, CVS, skin, eyes	NA	
Sulfate 14808-79-8 ***TB MED 577**	300	100	NA	Ingestion can cause laxative effects which can lead to dehydration, with symptoms of discomfort, weariness, apathy, impaired coordination, and delirium.	GI tract	NA	Laxative effects occur at doses greater than 1490 mg (300 mg/L).
Terbufos 13071-79-9	0.00035	0.00012	D	Nausea, vomiting, abdominal cramps, diarrhea, excessive salivation, headache, dizziness, weakness, excessive tearing and salivation, ocular pain, blurred vision, constricted pupils, incoordination, slurred speech, muscle twitches, mental confusion, drowsiness, difficulty breathing, cyanosis, cardiac irregularities, incontinence, convulsions, and coma. Cumulative toxicity is possible.	CNS, CVS, ChE Inh	NA	
Tetrachlorodibenzo-dioxin (2,3,7,8-) (TCDD) 1746-01-6	1.4E-08	4.7E-09	B2	Headache, nausea, vomiting, severe muscle pain, liver damage, chloracne, porphyria cutanea tarda, hair loss, hyperpigmentation, polyneuropathy, neurobehavioral effects, possible immunosuppression, thymic atrophy, liver damage. Cumulative toxicity; cancer.	Liver, skin, kidneys, blood, REPR	NA	Single oral lethal doses have been estimated to be greater than 100 ?g/kg (1.4 mg/L). The minimum cumulative toxic dose has been estimated to be 0.1 ?g/kg.
Toluene 108-88-3	3	1	D	Fatigue, nausea, weakness, confusion; higher concentrations can cause headache, vomiting, diarrhea, depressed respiration, loss of muscle coordination.	CNS	NA	CHID under development.
Toxaphene 8001-35-2	0.014	0.005	B2	Salivation, restlessness, hyperexcitability, tremors, spasms and convulsions. Liver and kidney degeneration; possible immune system suppression; cancer.	CNS	NA	The acute oral LD_{50} has been estimated to be 60 mg/kg.

Chemical CAS No.	5 L/day † 1-yr MEG (mg/L)	15 L/day † 1-yr MEG (mg/L)	Cancer Group	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Trifluralin 1582-09-8	0.1	0.03	C	Liver and kidney changes, anemia, CNS depression. Occasional vomiting, kidney and liver damage; decreased white and red blood cell counts; cancer.	CNS, liver, kidneys, blood	NA	
Trimethylbenzene (1,2,4-) 95-63-6	0.7	0.23	NA	Irritation of skin, eyes, nose, throat, bronchitis, anemia, drowsiness, fatigue, nausea	Eyes, skin, respiratory system., CNS, blood	NA	
Trimethylbenzene (1,3,5-) 108-67-8	0.7	0.23	NA	Irritation of skin, eyes, nose, throat, bronchitis, anemia, drowsiness, fatigue, nausea	Eyes, skin, RS, CNS, blood	NA	
Vanadium 7440-62-2	0.1	0.03	NA	Vanadium salts can cause abdominal cramping, diarrhea, black stools, and green tongue; bone marrow depression leading to changes in numbers of white and red blood cells. High concentrations can cause tremors, headache, and tinnitus. Irregular or slow heartbeat, kidney damage.	Bone, kidneys, CNS	NA	Metallis vanadium has low oral toxicity. It is ubiquitous in soils and approximately 20 ?g are normally ingested daily. However, ingestion of 60-120 mg or a vanadium salt may be fatal. Pentavalent forms and vanadates are the most toxic. The effects shown in the table are primarily those of vanadium salts.
Xylene 1330-20-7	40	13	D	Headache, weakness, dizziness, confusion, nausea, vomiting, abdominal pain, shivering, incoordination, loss of appetite, tremors, disturbed vision, salivation, and difficulty breathing; liver and kidney damage, and cardiac arrhythmias are possible.	CNS, liver, kidneys, blood, GI tract	NA	

Chemical CAS No.	5 L/day † 1-yr MEG (mg/L)	15 L/day † 1-yr MEG (mg/L)	Cancer Group	Potential Symptoms	Target Organs and Systems	Odor, Taste Threshold ‡	Notes §
Zinc 7646-85-7	4	1.3	NA	Severe stomach irritation, nausea, vomiting, and diarrhea (for zinc chloride).	GI tract	NA	

Footnotes on next page.

FOOTNOTES FOR TABLE D-2 – LONG-TERM WATER-MEG VALUES

† In temperate conditions, the estimated rate of consumption is 5 L/day. In arid regions, the estimated rate of consumptions is 15 L/day.

‡ The sources for odor and taste thresholds in water were the USEPA, Health Advisory for individual chemicals and the National Library of Medicine's Hazardous Substance Database (HSDB).

§ This column shows oral doses that have been estimated to cause the indicated toxic effects. The reported doses were converted into concentrations in water (shown in parentheses) for 5 liters/day consumption rates. Divide by 3 to convert to 15 liters/day consumption rates. Estimated lethal doses and approximate toxic effect levels were obtained from the TOMES database software system, from Gosselin et al (1976), from Hayes, *Pesticides Studied in Man*, and from the EPA Health Advisory Source documents.

***TB MED 577** -- These values were taken from *TB MED 577, they are STANDARDS and should not be exceeded.
*Department of the Army (DA). *Sanitary Control And Surveillance Of Field Water Supplies*, Final Draft Technical Bulletin, Medical (TBMED) 577, May 1999.

Other values obtained from following hierarchy sources [USEPA HA-ADJ ≥ ATSDR MRL-ADJ> USEPA RFD–ADJ] unless otherwise noted (see RD 230 for more details):

US EPA primary sources:

-U.S. Environmental Protection Agency (USEPA), 1996a. 822-R-96-001, *Drinking Water Regulations and Health Advisories*, Office of Water, United States Environmental Protection Agency, October 1996.U.S. Environmental Protection Agency (USEPA), 1996b. Soil Screening Guidance: User's Guide. Office of Solid Waste and Emergency Response. Washington D.C

-U.S. Environmental Protection Agency (USEPA), 1999a. *Integrated Risk Information System (Iris)*. Environmental Criteria And Assessment Office, Office Of Health And Environmental Assessment, Cincinnati, Ohio

-U.S. Environmental Protection Agency (USEPA), 1997a. *Health Effects Summary Tables (Heast)*. 1997. USEPA 540/R-97-036, Pb97-921199. Office Of Research And Development, Office Of Emergency And Remedial Response, U.S Environmental Protection Agency, Washington D.C

ATSDR primary sources :

- Agency for Toxic Substances and Disease Registry (ATSDR), 1996. *Toxicological Profiles*. Prepared by Clement International Corporation under Contract No. 205-88-0608. Prepared for U.S. Department of Health and Human Services, Public Health Service, Washington, D.C.

CHID – Chemical Hazard Information for Deployments. Additional Fact Sheet information is under development for notated Chemicals..
BW – Body weight
EEG – electroencephalogram (brain waves)
LC_{Lo} – Lethal Concentration – low (estimate of small percentage (e.g. 1-5 %) exposed will succumb lethally
MRL – Minimum Risk Level
NA – Not Available;
PAH – Polycyclic Aromatic Hydrocarbon
UD- Under development

Target organ/systems, Carcinogenicity, and units information next page……

TABLE 2-4-1. TARGET ORGANS

TARGET ORGANS	
Eyes	Brain
Skin	Heart
Blood	Pancreas
Bladder	Adrenal Glands
Thyroid	Lungs
Bone	Liver
Fetus	Kidneys
Spleen	

TABLE 2-4-2. TARGET SYSTEMS

TARGET SYSTEMS	
CNS – Central Nervous System	CVS – Cardiovascular System
PNS – Peripheral Nervous System	ChE Inh – Cholinesterase Inhibitor
GI tract – Gastrointestinal Tract	UT – Urogenital Tract
RS – Respiratory System	CRC – Circulatory System
LRS – Lower Respiratory System	IMM – Immune System
URS – Upper Respiratory System	REPR – Reproductive System
ENDO – Endocrine System	HEM – Hemopoietic System
LYMP – Lymphatic System	

Units used:

g – gram
mg = milligram
L = Liter
mL = milliliter
mg/kg/day == milligram chemical per kilogram body weight (ingested) per day

µg/kg = micrograms per kilogram = ppb = parts per billion
mg/L = milligram per liter = ppm = part per million

Cancer Class Categories:

The scheme used by the USEPA for categorizing chemicals according to their carcinogenic potential is as follows (see Section 2.4.3):
Group A: Human carcinogen
Group B: Probable human carcinogen:
Group B1 - Limited evidence in epidemiological studies
Group B2 - Sufficient evidence from animal studies
Group C: Possible human carcinogen Limited evidence from animal studies and inadequate or no data in humans.
Group D: Not classifiable
Group E: No evidence of carcinogenicity

CHEMICAL INDEX (WATER)

APPENDIX E

MILITARY EXPOSURE GUIDELINES FOR SOIL

CONTENTS

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TABLE E-1. LONG-TERM, SOIL MILITARY EXPOSURE GUIDELINES (1 YEAR DEPLOYMENT)

Chemical CAS No.	1-yr soil MEG (mg/kg)	Cancer Class	Potential Symptoms †	Target Organs and Systems	Notes §
Acenaphthene 83-32-9	1300	NA	May cause slight changes in the liver.	Liver	Inhalation not included in derivation of this value (PAH). MEG based on Csat. At this level, inhalation is the most probable route of exposure. Refer to 1-year Air-MEG.
Acenaphthylene 208-96-8	UD	D	As with other PAHs, toxicity following short-term exposure is minimal. Long-term exposure to PAHs can produce a variety of non-cancer effects including irritation of the eyes and photosensitivity, mild liver or kidney damage, anemia and other changes in the blood cells.	Liver, kidneys, blood, IMM	No data are available upon which to base guidelines for this chemical.; inhalation not considered in derivation of this value (PAH).
Acetone 67-64-1	16	D	Eye, nose and throat irritation, headache, dizziness, CNS depression, dermatitis.	Eyes, skin, RS, CNS	MEG based on Csat. At this level, inhalation is the most probable route of exposure. Refer to 1-year Air-MEG.
Alachlor 15972-60-8	1000	B2	May damage the liver, kidney, and spleen; cancer.	Liver, kidneys, spleen	
Aldrin 309-00-2	3	B2	Nausea, vomiting, diarrhea, hyperexcitability, tremors, limb jerks, convulsions, and ventricular fibrillation; reversible kidney and liver injury; cancer.	CNS, liver, kidneys	Ingestion of 25.6 mg/kg BW can produce convulsions; a single oral dose of 5 g (71 mg/kg BW) is lethal.

Chemical CAS No.	1-yr soil MEG (mg/kg)	Cancer Class	Potential Symptoms †	Target Organs and Systems	Notes §
Anthracene 120-12-7	6.1	D	Contact may make the skin more susceptible to the effects of sunlight. Long-term exposure to PAHs can produce a variety of non-cancer effects including irritation of the eyes and photosensitivity, mild liver or kidney damage, anemia and other changes in the blood cells.	Liver, kidneys, blood, IMM, skin	Inhalation not considered in derivation of this value. MEG based on Csat. At this level, inhalation is the most probable route of exposure. Refer to 1-year Air-MEG (PAH).
Aroclor-1016 12674-11-2	7.4	NA	Nausea, vomiting, liver damage, facial edema, abdominal pain, weight loss, diarrhea; headache, dizziness, depression, weakness, transient visual disturbances; chloracne; birth defects, peripheral nerve damage. Cumulative toxicity; liver and kidney damage.	CNS, liver, kidneys	PCB. Minimal oral dose expected to cause symptoms is 500 mg (7 mg/kg BW). Can be absorbed dermally – in one case of acute dermal exposure, a worker exposed to polychlorinated biphenyls developed hyperpigmentation, skin thickening and photosensitivity.
Aroclor-1254 11097-69-1	5.2	NA	Nausea, vomiting, liver damage, facial edema, abdominal pain, weight loss, diarrhea; headache, dizziness, depression, weakness, transient visual disturbances; chloracne; birth defects, peripheral nerve damage. Cumulative toxicity, liver and kidney damage.	CNS, liver, kidneys	Minimal oral dose expected to cause symptoms is 500 mg (7 mg/kg BW). Can be absorbed dermally – in one case of acute dermal exposure, a worker exposed to polychlorinated biphenyls developed hyperpigmentation, skin thickening and photosensitivity.

Chemical CAS No.	1-yr soil MEG (mg/kg)	Cancer Class	Potential Symptoms †	Target Organs and Systems	Notes §
Arsenic 7440-38-2	1100	A	Facial swelling, vomiting, loss of appetite, abdominal pain; diarrhea, shock, muscle cramps, headache, chill, cardiac abnormalities, decreased white blood cell count, and enlargement of liver; delayed effects include sensory and motor peripheral polyneuropathies. Hyperpigmentation of the skin (especially on the palms of the hands and soles of the feet), anemia, weakness, incoordination, mental confusion, cirrhosis of the liver, hair loss and nail changes; cancer.	Liver, kidneys, blood, CNS, GI tract, IMM	CHID under development.
Benzene 71-43-2	310	A	Vomiting, loss of coordination, light-headedness, headache, anemia, shallow/rapid pulse, loss of concentration, delirium, chemical pneumonitis, dizziness, pallor, flushing, weakness, and breathlessness; high concentrations may cause convulsions, coma, or irregular heart beat. Fatigue, headache, dizziness, nausea, loss of appetite, weakness, nosebleeds, pallor, and bleeding gums; bone marrow damage; immunosuppression; cancer.	Eyes, skin, RS, blood, CNS, IMM, HEM	The mean lethal oral dose has been estimated to be 13 g (186 mg/kg BW). Acute erythema, blistering and dermatitis may develop from dermal exposure; skin absorption from acute dermal exposure can cause CNS effects. CHID under development.

Chemical CAS No.	1-yr soil MEG (mg/kg)	Cancer Class	Potential Symptoms †	Target Organs and Systems	Notes §
Benzo(a)anthracene 56-55-3	2500	B2	As with other PAHs, toxicity following short-term exposure is minimal. Long-term exposure to PAHs can produce a variety of non-cancer effects including irritation of the eyes and photosensitivity, mild liver or kidney damage, anemia and other changes in the blood cells. Skin contact may cause irritation, erythema (redness), warts or polyps, and skin cancer.	Liver, kidneys, blood, IMM	Inhalation not considered in derivation of this value. MEG based on Csat. At this level, inhalation is the most probable route of exposure. Refer to 1-year Air-MEG (PAH).
Benzo(a)pyrene 50-32-8	250	B2	Toxicity from short-term exposure is low. Long-term exposure may cause depression of the immune system; mild liver or kidney damage; changes in the blood composition such as aplastic anemia and pancytopenia; and cancer. Effects on the developing fetus have been observed in laboratory animals.	Liver, kidneys, blood, IMM	Inhalation not considered in derivation of this value. MEG based on Csat. At this level, inhalation is the most probable route of exposure. Refer to 1-year Air-MEG (PAH).
Benzo(b)fluoranthene 205-99-2	2500	B2	Toxicity from short-term exosure is low. Long-term exposure may cause depression of the immune system; mild liver and kidney damage; anemia and other changes in the blood cells; and cancer. Skin contact may cause irritation, erythema (redness), warts or polyps, and skin cancer.	Liver, kidney, blood, IMM	Inhalation not considered in derivation of this value. MEG based on Csat. At this level, inhalation is the most probable route of exposure. Refer to 1-year Air-MEG (PAH).

Chemical CAS No.	1-yr soil MEG (mg/kg)	Cancer Class	Potential Symptoms †	Target Organs and Systems	Notes §
Benzo(k)fluoranthene 207-08-9	3100	B2	Toxicity from short-term exosure is low. Long-term exposure may cause depression of the immune system; mild liver and kidney damage; anemia and other changes in the blood cells; and cancer. Skin contact may cause irritation, erythema (redness), warts or polyps, and skin cancer.	Liver, kidney, blood, IMM	Inhalation not considered in derivation of this value. MEG based on Csat. At this level, inhalation is the most probable route of exposure. Refer to 1-year Air-MEG (PAH).
Beryllium 7440-41-7	16000	B2	Low acute toxicity by ingestion. Rickets (fragile or weakened bones); cancer.	Bone	Evidence of carcinogenicity from inhaled beryllium.
Bis (2-ethylhexyl) phthalate 117-81-7	2900	B2	Eye irritation, liver damage, possible teratogenic and carcinogenic effects.	Eyes, skin, RS., CNS, liver, REPR, GI tract	
Sec-Butylbenzene 135-98-8	230	NA	Irritation of eyes, nose, throat, and skin, CNS depression, incoordination, nausea, general anesthetic effects.	Eyes, RS, skin	MEG based on Csat. At this level, inhalation is the most probable route of exposure. Refer to 1-year Air-MEG.
Cadmium 7440-43-9	130	B1	Nausea, vomiting, diarrhea, muscle cramps, salivation, sensory disturbances, liver injury, convulsions, shock, and renal failure. Pain resulting from softening or decalcification of the bones, osteoporosis, irreversible kidney disease, anemia; cancer.	Kidneys, liver	Ingestion of 3 mg (0.043 mg/kg BW) may cause vomiting; 30 mg (0.43 mg/kg/ BW) of soluble cadmium salts can produce severe toxic symptoms; 350 mg (5 mg/kg BW) may be fatal.

Chemical CAS No.	1-yr soil MEG (mg/kg)	Cancer Class	Potential Symptoms †	Target Organs and Systems	Notes §
Carbon disulfide 75-15-0	720	NA	Dizziness, headache, nausea, vomiting, diarrhea, fatigue, palpitations and weakness; high concentrations may cause psychosis, tremor, delirium, coma, muscle spasm, convulsions, difficulty breathing, and liver damage. Decreased fertility in males and females.	CNS, PNS, liver, REPR	Systemic effects can occur from skin absorption following severe skin irritation. MEG based on Csat. At this level, inhalation is the most probable route of exposure. Refer to 1-year Air-MEG.
Chlordane 57-74-9	62	B2	Nausea, vomiting, diarrhea, headache, excitability, confusion, weakness, incoordination; high concentrations may cause delirium, muscle spasms, convulsions or seizures, coma, pulmonary edema, and difficulty breathing. Kidney and liver degeneration; blood dyscrasias; cancer.	CNS, liver, kidneys	Ingestion of 28 to 56 mg/kg BW may cause severe effects such as convulsions. The fatal human dose lies between 6 and 60 g. The onset of symptoms occurs 45 minutes to several hours after ingestion. Can be absorbed through the skin.
Chloromethane (Methyl chloride) 74-87-3	3700	C	Headache, drowsiness, giddiness, dizziness, confusion, incoordination, vomiting, abdominal pain, diarrhea, breathing difficulties; high concentrations may cause unconsciousness, convulsions, coma, visual disturbances, and may damage the kidneys, liver, or blood; cancer.	CNS, liver, kidneys, REPR	Symptoms of chloromethane exposure may be delayed in onset. Bronchospasm can develop from constant skin absorption.

Chemical CAS No.	1-yr soil MEG (mg/kg)	Cancer Class	Potential Symptoms †	Target Organs and Systems	Notes §
Chlorothalonil 1897-45-6	1500	B2	Vomiting, rapid breathing, GI irritation, weakness, and sedation. Cumulative toxicity; incoordination, rapid breathing, hematuria (blood in the urine), nosebleed, delayed hypersensitivity; cancer.	CNS, GI tract, UT	
Chromium (total) 7440-47-3	5700	D	The toxicity of chromium has been attributed primarily to hexavalent chromium compounds.	Kidneys, liver	
Chromium III 16065-83-1	390000	D	Hexavalent chromium compounds are more toxic than trivalent chromium compounds.	Kidneys, liver	
Chromium VI 18540-29-9	5300	A	Ingestion of hexavalent chromium compounds may cause GI irritation, epigastric pain, nausea, vomiting, diarrhea, liver and kidney damage, internal bleeding, circulatory collapse, unconsciousness, and death. Reduced fertility and birth defects are possible; cancer.	Kidneys, liver	Doses of 0.5 – 1.5 g (7-21 mg/kg) BW $K_2Cr_2O_7$ have been fatal. Carcinogenic via inhalation; carcinogenicity via oral ingestion cannot be determined and is classified as Group D.

Chemical CAS No.	1-yr soil MEG (mg/kg)	Cancer Class	Potential Symptoms †	Target Organs and Systems	Notes §
Chrysene 218-01-9	3100	B2	Toxicity from short-term exposure is low. Long-term exposure may cause depression of the immune system; mild liver and kidney damage; anemia and other changes in the blood cells; and cancer. Skin contact may cause irritation, erythema (redness), warts or polyps, and skin cancer.	Liver, kidneys, blood, IMM	Inhalation not considered in derivation of this value. MEG based on Csat. At this level, inhalation is the most probable route of exposure. Refer to 1-year Air-MEG (PAH).
Cumene 98-82-8	640	D	Irritation to eyes, skin, mucous membranes; dermatitis; headache, narcosis, coma.	CNS, URS, eyes, skin	MEG based on Csat. At this level, inhalation is the most probable route of exposure. Refer to 1-year Air-MEG.
Cyanide 57-12-5	110000	D	Headache, breathlessness, weakness, palpitation, nausea, vomiting, giddiness, tremor, rapid heart beat, dizziness, confusion, anxiety, agitation, confusion, cardiac arrhythmias, seizures, stupor, and coma. CNS effects (insomnia, memory loss, tremors); degeneration of spinal cord and optic nerve; enlargement of the thyroid gland; reduced fertility and birth defects are possible.	CNS, RS, CVS, liver, kidneys	Concentrations between 0.9 and 1.7 mg/kg BW may cause changes in blood chemistry without clinical effects. Severe but reversible symptoms may occur at concentrations of 1.7 to 3.4 mg/kg BW; concentrations higher than 3.4 mg/kg BW life-threatening toxicity.

Chemical CAS No.	1-yr soil MEG (mg/kg)	Cancer Class	Potential Symptoms †	Target Organs and Systems	Notes §
2,4-D (2,4-Dichlorophenoxyacetic acid) 94-75-7	1000	D	Nervous system damage, vomiting, diarrhea, lethargy, incoordination, weakness, paralysis, stupor, miosis, stiffness in the extremities, muscle twitching and spasms , lowered blood pressure, convulsions; transient liver and kidney damage; may cause birth defects and reduced fertility. Cumulative toxicity; CNS, kidney, and liver damage.	CNS, liver, kidneys	Ingestion of a single dose of 5 mg/kg BW and repeated doses of 7 mg/kg /day for 21 days caused no effects. The single oral lethal dose has been estimated to be 355 mg/kg BW. Survival following a dose of about 110 mg/kg BW has been reported. May be dermally absorbed.
P,p'-DDT 50-29-3	52	B2	Vomiting, tingling of lips, tongue, and face; malaise, headache, sore throat, fatigue, tremors; apprehension, ataxia, confusion, convulsions, coma and partial paralysis. Estrogenic effects; may reduce fertility; cancer.	Eyes, skin, CNS, kidneys, liver, PNS	
Diazinon 333-41-5	52	E	Nausea, vomiting, diarrhea, headache, dizziness, weakness, excessive tearing and salivation, ocular pain, blurring/dimness of vision, miosis, loss of muscle coordination, slurred speech, muscle twitching, disorientation, drowsiness, difficulty breathing, hypertension, hypotention, cardiac arrhythmias, random jerky movements, incontinence, convulsions, and coma. Cumulative toxicity; loss of visual acuity.	Eyes, RS, CNS, CVS, blood, ChE Inh	Is efficiently absorbed through skin.

Chemical CAS No.	1-yr soil MEG (mg/kg)	Cancer Class	Potential Symptoms †	Target Organs and Systems	Notes §
Dibromochloropropane 96-12-8	210	B2	GI distress; may damage the kidney, liver, and testes. Kidney and liver damage, atrophy of the testes and sterility in males; cancer.	Liver, CNS, kidneys, spleen, REPR, GI tract	
Dieldrin 60-57-1	5.2	B2	Early signs of toxicity are headache, dizziness, nausea, vomiting, malaise, sweating, tremors, limb jerks, EEG changes, convulsions, and coma; secondary effects include hypertension, cardiac arrhythmias, and fever; sleep, memory, behavioral disturbances, headache, and convulsions may persist for months following exposure. Cumulative toxicity; fainting, muscle spasms, tremors, weight loss, reduced psychomotor skills, hemolytic anemia; reproductive effects may occur; cancer.	CNS	No effects were seen in volunteers given doses of 0.21 mg. Serious effects may occur at a dose of 10 mg/kg BW; 29 mg/kg BW caused profuse vomiting or prolonged convulsions; the acute mean lethal dose for humans has been estimated to lie between 20 and 70 mg/kg BW. Oral doses of dieldrin ranging from 10 to 211 ?g over a period of 18 months had no adverse effects in volunteers. Dieldrin is readily absorbed through skin.
Dinitrobenzene (1,3-) 99-65-0	450	D	Methemoglobinemia associated with headache, irritability, dizziness, weakness, nausea, lethargy, shortness of breath, liver damage. May cause reduced fertility and birth defects.	Blood, liver, CNS, CVS	The lethal dose has been estimated to lie between 5 and 50 mg/kg BW. It is readily absorbed through skin; acute dermal exposure can cause yellowing of skin.

Chemical CAS No.	1-yr soil MEG (mg/kg)	Cancer Class	Potential Symptoms †	Target Organs and Systems	Notes §
Dinoseb 88-85-7	100	D	Nausea, vomiting, abdominal pain, marked thirst, fatigue, sweating, facial flushing, rapid heart beat, fever, weight loss, respiratory distress, cyanosis, restlessness, anxiety, muscle cramps, excitement, convulsions, and coma. Liver or kidney damage; cataracts; may affect fertility.	CNS, REPR	
Disulfoton 298-04-4	30	NA	Headache, loss of appetite, nausea, vomiting, abdominal cramps, diarrhea, weakness, dizziness, confusion, slurred speech, salivation, tearing, profuse sweating, shortness of breath, tightness of the chest, changes in heart rate, cyanosis, moisis, blurred vision, runny nose, slow pulse, muscle twitching, tremors, muscle cramps, incoordination, convulsions, coma, and shock. Decreased visual acuity, liver injury, altered tendon reflexes.	Eyes, RS, CNS, CVS, ChE Inh	Oral doses of 0.75 mg/day for 30 days produced no significant effects in volunteers. The human LD_{50} has been estimated to be 5 mg/kg BW.
Endrin 72-20-8	45	D	Headache, dizziness, nausea, vomiting, hypersalivation, insomnia, lethargy, weakness, agitation and confusion; high concentrations may cause convulsions, stupor, tremors, and coma; headache, dizziness, sleepiness, weakness, and loss of appetite may persist for 2 to 4 weeks.	CNS	Convulsions may be induced in humans by doses of 0.2 to 0.25 mg/kg BW; a dose of 1 mg/kg can induce repeated seizures. Endrin can be absorbed through the skin.

Chemical CAS No.	1-yr soil MEG (mg/kg)	Cancer Class	Potential Symptoms †	Target Organs and Systems	Notes §
Ethyl benzene 100-41-4	230	D	Headache, nausea, weakness, dizziness, sleepiness, fatigue, loss of coordination, and coma.	CNS	MEG based on Csat. At this level, inhalation is the most probable route of exposure. Refer to 1-year Air-MEG.
Ethylene dibromide 106-93-4	0.37	B2	Liver and kidney damage, vomiting, excitement and other CNS effects; may affect fertility in males; cancer.	CNS, liver, kidneys, REPR	A single oral dose of 65 mg/kg BW may be lethal. May be absorbed through skin.
Fenamiphos 22224-92-6	52	D	Nausea, vomiting, abdominal cramps, diarrhea, salivation, headache, dizziness, weakness, runny nose, blurred vision, constricted pupils, incoordination, slurred speech, muscle twitches, random jerky movements, mental confusion, disorientation, drowsiness, difficulty breathing, cardiac irregularities, incontinence, convulsions, and coma. Cumulative toxicity.	CNS, CVS, ChE Inh	May be absorbed through the skin.
Fluoranthene 206-44-0	42000	D	Toxicity from short-term exposure is low. Long-term exposure may cause depression of the immune system; mild liver and kidney damage; anemia and other changes in the blood cells. Skin contact may cause irritation, erythema (redness), warts or polyps.	Liver, kidney, blood, IMM	Inhalation not considered in derivation of this value
Fluorene 86-73-7	90	D	Eye or skin irritation.	Skin, eyes	MEG based on Csat. At this level, inhalation is the most probable route of exposure. Refer to 1-year Air-MEG.

Chemical CAS No.	1-yr soil MEG (mg/kg)	Cancer Class	Potential Symptoms †	Target Organs and Systems	Notes §
Fonofos 944-22-9	220	D	Loss of appetite, nausea, vomiting, abdominal cramps, diarrhea, headache, dizziness, weakness, confusion, blurred vision, constricted pupils, slurred speech, profuse sweating, salivation, and runny nose; cardiac irregularities, difficulty breathing, muscle twitching, paralysis, convulsions, coma, or respiratory arrest may occur. Nervous behavior, tremors, liver damage, GI effects, increased nasal, salivary and lacrimal secretions.	CNS, CVS, ChE Inh	May be absorbed through the skin.
GA (TABUN) 77-81-6	4.6	NA	Nausea, vomiting, abdominal cramps, diarrhea, headache, giddiness, dizziness, weakness, excessive tearing, blurred or dim vision, miosis, loss of muscle coordination, slurred speech, muscle twitching, confusion, disorientation, drowsiness, difficulty breathing, excessive salivation, cardiac arrhythmias, random jerking movements, incontinence, convulsions, coma.	CNS, ChE Inh	See Table C-1 for additional info
GB (Sarin) 107-44-8	2.7	NA	SEE GA	SEE GA	See Table C-1 for additional info
GD (Soman) 96-64-0	0.27	NA	SEE GA	SEE GA	See Table C-1 for additional info

Chemical CAS No.	1-yr soil MEG (mg/kg)	Cancer Class	Potential Symptoms †	Target Organs and Systems	Notes §
Heptachlor 76-44-8	2	B2	Nausea, vomiting, diarrhea, kidney and liver damage; hyperexcitability, tremors, convulsions, and paralysis. Cumulative toxicity; blood dyscrasias. Reduced fertility has been observed in animal studies; cancer.	CNS, liver	A dose of 1 to 3 g has been estimated to cause serious symptoms in humans, especially liver impairment; can be absorbed through skin; estimated dermal toxicity for single exposure is 46 g (657 mg/kg BW) and 1.2 g/day (17 mg/kg BW) for multiple exposure.
Heptachlor epoxide 1024-57-3	1.5	B2	Apprehension, agitation, muscle twitching and spasms, tremor, incoordination, vomiting, GI upset, abdominal pain; convulsions; kidney injury and liver damage; cancer.	CNS, liver	
Hexachlorobenzene 118-74-1	31	B2	Headache, nausea, cyanosis, muscle spasm, convulsions, liver injury, birth defects. Porphyria cutanea tarda, enlargement of the thyroid and lumph nodes, reduced bone density, skin photosensitization, liver, kidney, and lung damage; cancer.	CNS, blood, liver, kidneys	

Chemical CAS No.	1-yr soil MEG (mg/kg)	Cancer Class	Potential Symptoms †	Target Organs and Systems	Notes §
Lead 7439-92-1	2200	B2	Loss of appetite, malaise, insomnia, headache, irritability, muscle and joint pains, cramping abdominal pain, tremors, hallucinations, distorted perceptions, muscle weakness, gastritis, skin pallor due to anemia, and dark gray-blue lines of lead sulfide visible in gums. Hypertension, irreversible kidney damage; may affect fertility and reproduction (fetal effects); cancer.	CNS, blood, kidneys, GI tract, CVS; REPR, fetus	Continuous long-term ingestion exposure through soil to levels exceeding this MEG may result in blood lead levels greater than 30 ug/dl, which is the OSHA recommended level for individuals planning to have children. However, OSHA allows 40 ug/dl as a "permissible" blood lead level in exposed workers below which no further medical monitoring or workplace intervention is required. The MEG of lead is based on USEPA's recommendation for nonresidential soil cleanup level (range 2000-5000 ppm) since toxicity information is currently unavailable. (Check: TSCA, Section 403). CHID under development.
Lead (Tetraethyl) 78-00-2	0.026		Anxiety, irritability, insomnia, nightmares, lack of appetite, nausea, vomiting, diarrhea, headache, muscle weakness, restlessness, visual difficulties, fatigue, bradycardia, hypotension, delusions, incoordination, mania, psychosis, hallucinations, convulsions, coma, and death; reproductive effects may be possible. Cumulative toxicity, ataxia, tremors, polyneuropathy.	CNS	
Lewisite 542-25-3	11	NA*	Nausea, vomiting, diarrhea, abdominal pain, intense thirst, restlessness, weakness, hypotension, and hypothermia.	GI tract, heart, brain, kidneys	Breakdown of lewisite is rapid in the environment; lewisite and degradation products contain arsenic which is carcinogenic (see arsenic).

Chemical CAS No.	1-yr soil MEG (mg/kg)	Cancer Class	Potential Symptoms †	Target Organs and Systems	Notes §
Lindane 58-89-9	560	C	Irritability, restlessness, insomnia, anxiety, dizziness, malaise, headache, nausea, fever, cyanosis, vomiting, and loss of muscle coordination; higher exposure can cause muscle spasms, seizures, and convulsions. Liver and kidney damage; may affect fertility; cancer.	CNS, REPR	The mean lethal dose is approximately 400 mg/kg BW. Can be absorbed through the skin.
Malathion 121-75-5	2200	D	Miosis, blurred vision, tearing, increased salivation, weakness, nausea, vomiting, abdominal cramps, diarrhea, giddiness, confusion, loss of muscle coordination, runny nose, headache, chest tightness, difficulty breathing, pulmonary edema, muscle twitching, coma, respiratory distress, cardiac irregularities, and convulsions. Chronic exposures can cause fatigue, visual disturbances, headache, nausea, abdominal pain, and twitching; kidney and liver damage; may affect fertility.	Lungs, liver, CNS, heart, ChE Inh	No effects were seen in volunteers after a single oral dose of 0.84 mg/kg BW or repeated doses of 16 mg/day BW for 47 days. The fatal dose is believed to be between 350-1000 mg/kg BW.

Chemical CAS No.	1-yr soil MEG (mg/kg)	Cancer Class	Potential Symptoms †	Target Organs and Systems	Notes §
Mercury (inorganic) 7439-97-6	33	D	Tremors, peripheral neuropathy, fatigue, memory loss, personality changes, kidney damage, cough, chest pain, difficulty breathing, liver damage, diarrhea, nausea, vomiting. Reduced visual acuity, tremor, ataxia, nerve fiber degeneration, loss of taste, smell, change in motor function, loss of higher mental function, irritability, headache, fatigue, weakness, loss of memory, depression, insomnia, apathy, hallucinations, seizures, mania; birth defects, kidney damage, dementia.	CNS	Dermal exposure can lead to systemic toxicity particularly if the skin is broken.
Mercury (Methyl) 22967-92-6	31	C	Paresthesia, impaired hearing, taste and smell; slurred speech, unsteady gait, muscle weakness, irritability, memory loss, depression, insomnia, ataxia, loss of visual acuity, tremors, confusion, hallucinations, excitement, loss of consciousness; nerve degeneration. Reproductive effects are possible; cancer.	CNS, kidneys	Single oral doses of 10-60 mg/kg BW have been fatal. Methyl mercury can be dermally absorbed.
Methyl ethyl ketone 78-93-3	34000	D	Irritation, CNS, reproductive effects.	Fetus, CNS	MEG based on Csat. At this level, inhalation is the most probable route of exposure. Refer to 1-year Air-MEG.

Chemical CAS No.	1-yr soil MEG (mg/kg)	Cancer Class	Potential Symptoms †	Target Organs and Systems	Notes §
Methyl parathion 298-00-0	310	D	Nausea, vomiting, abdominal cramps, diarrhea, salivation, headache, weakness, giddiness, dizziness, runny nose, blurred vision, miosis, cardiac arrhythmias and ischemia, difficulty breathing; muscle twitch, convulsions, liver and kidney damage, coma and respiratory paralysis are possible at high concentrations. Cumulative toxicity.	Eyes, CNS, CVS, liver, kidneys, ChE Inh	Volunteers receiving oral doses of 22 mg/day suffered no ill effects. Depression of red blood cell cholinesterase occurred at doses of 30 mg/day which was considered to be the level of minimal toxicity. Ingestion of 50 to 200 g has resulted in death; the minimum adult lethal dose by the oral route may be less than 1.84 g. Can be absorbed through the skin.
Molybdenum 7439-98-7	1300	NA	Weight loss, diarrhea, poor muscle coordination, headaches, muscle or joint aching. Changes in liver function, gout, anemia.	Liver, kidneys, blood	
Naphthalene 91-20-3	220	C	Headache, profuse perspiration, confusion, listlessness, lethargy, muscle twitching, coma; nausea, vomiting, abdominal cramps, diarrhea; hemolytic anemia, methemoglobinemia; cataracts, liver and kidney damage.	Eyes, blood, liver, kidneys, CNS	MEG based on Csat. At this level, inhalation is the most probable route of exposure. Refer to 1-year Air-MEG (PAH).
Oxamyl (Vydate) 23135-22-0	3000		Tremors, blurred or dim vision, increased salivation, tearing, incontinence, diarrhea, abdominal cramps, nausea, vomiting, and difficulty breathing; convulsions, coma, and respiratory paralysis are possible at high concentrations; protracted malaise and weakness may persist after apparent recovery.	ChE Inh	

Chemical CAS No.	1-yr soil MEG (mg/kg)	Cancer Class	Potential Symptoms †	Target Organs and Systems	Notes §
Paraquat 1910-42-5	1100	C	Abdominal cramping, nausea, vomiting, bloody diarrhea, headache, difficulty swallowing, fever, decreased blood pressure; higher concentrations can cause heart, kidney and liver injury and extensive lung damage with difficulty breathing, pulmonary fibrosis and edema; may reduce fertility in males. Edema, interstitial bleeding; lung, kidney, and liver damage; cancer.	Lungs, liver, kidneys, GI tract	Single oral doses of 1 to 4 g have caused fatalities.
Phenanthrene 85-01-8	270	D	Contact may make the skin more susceptible to the effects of sunlight (photosensitization). As with other polycyclic aromatic hydrocarbons (PAHs), toxicity following short-term exposure is low. Long-term exposure to PAHs can produce a variety of non-cancer effects including irritation of the eyes and photosensitivity, mild liver or kidney damage, anemia and other changes in the blood cells, and immunosuppression.	Liver, kidneys, blood, IMM, skin	Inhalation not considered in derivation of this value. MEG based on Csat. At this level, inhalation is the most probable route of exposure. Refer to 1-year Air-MEG (PAH).

Chemical CAS No.	1-yr soil MEG (mg/kg)	Cancer Class	Potential Symptoms †	Target Organs and Systems	Notes §
Polychlorinated biphenyls 1336-36-3	2.1	B2	Exposure may cause skin and mucous membrane irritation, skin hyperpigmentation, chloracne, headache, abnormal liver function tests, hepatomegaly, malaise, peripheral neurotoxicity, liver disease and cirrhosis. Swelling of the face and eyelides, transient visual disturbances, hypothyroidism, GI distress, jaundice, and nephrotoxicity have also been reported.	PNS, liver, kidneys	
n-Propylbenzene 103-65-1	240	D	Irritation of eyes, nose, throat, and skin, CNS depression, incoordination, nausea, general anesthetic effects.	Eyes, RS, skin	MEG based on Csat. At this level, inhalation is the most probable route of exposure. Refer to 1-year Air-MEG (PAH).
Pyrene 129-00-0	31000	D	Pyrene is irritating to exposed skin and eyes. Contact may make the skin more susceptible to the effects of sunlight. As with other polycyclic aromatic hydrocarbons (PAHs), toxicity following short-term exposure is low. Long-term exposure to PAHs can produce a variety of non-cancer effects including irritation of the eyes and photosensitivity, mild liver or kidney damage, anemia and other changes in the blood cells, and immunosuppression.	Liver, kidneys, blood, IMM, skin	Inhalation not considered in derivation of this value. Refer to 1-year Air-MEG (PAH).

Chemical CAS No.	1-yr soil MEG (mg/kg)	Cancer Class	Potential Symptoms †	Target Organs and Systems	Notes §
Simazine 122-34-9	520	C	Incoordination, tremor, weakness, muscle spasms, difficulty breathing; cancer.	CNS, kidneys, liver	
Strontium 7440-24-6	140000	NA	Skin and eye irritation, altered heart function, bone abnormalities.	Bone, heart, skin, eyes	
Sulfur Mustard (HD) 505-60-2	0.51	A	Powerful skin irritation and blistering, severe eye injury, permanent loss of vision. Nausea, vomiting, and diarrhea can follow ingestion.	Eyes, skin, GI tract	Effects (e.g skin/eye irritation) are generally delayed 2-24 hours post exposure); any suspected exposure should be addressed by immediate and thorough decontamination (such as rinsing with 0.05 % bleach/water solution)
TCDD (2,3,7,8-) 1746-01-6	0.0048	B2	Headache, nausea, vomiting, severe muscle pain, liver damage, chloracne, porphyria cutanea tarda, hair loss, hyperpigmentation, polyneuropathy, neurobehavioral effects, possible immunosuppression, thymic atrophy, liver damage. Cumulative toxicity; cancer.	Liver, skin, kidneys, blood, REPR	Single oral lethal doses have been estimated to be greater than 100 ?g/kg BW. The minimum cumulative toxic dose has been estimated to be 0.1 ?g/kg BW.

Chemical CAS No.	1-yr soil MEG (mg/kg)	Cancer Class	Potential Symptoms †	Target Organs and Systems	Notes §
Terbufos 13071-79-9	2.6	NA	Nausea, vomiting, abdominal cramps, diarrhea, excessive salivation, headache, dizziness, weakness, excessive tearing and salivation, ocular pain, blurred vision, constricted pupils, incoordination, slurred speech, muscle twitches, mental confusion, drowsiness, difficulty breathing, cyanosis, cardiac irregularities, incontinence, convulsions, and coma. Cumulative toxicity is possible.	CNS, CVS, ChE Inh	
Toluene 108-88-3	520	D	Fatigue, nausea, weakness, confusion; higher concentrations can cause headache, vomiting, diarrhea, depressed respiration, loss of muscle coordination.	CNS	MEG based on Csat. At this level, inhalation is the most probable route of exposure. Refer to 1-year Air-MEG.
Toxaphene 8001-35-2	100	B2	Salivation, restlessness, hyperexcitability, tremors, spasms and convulsions. Liver and kidney degeneration; possible immune system suppression; cancer.	CNS	The acute oral LD_{50} has been estimated to be 60 mg/kg BW. Can be absorbed through the skin; skin absorption is enhanced by oils.
Trifluralin 1582-09-8	740	C	Liver and kidney changes, anemia, CNS depression. Occasional vomiting, kidney and liver damage; decreased kidney and liver damage; decreased white and red blood cell counts; cancer.	CNS, liver, kidneys, blood	

Chemical CAS No.	1-yr soil MEG (mg/kg)	Cancer Class	Potential Symptoms †	Target Organs and Systems	Notes §
Trimethylbenzene (1,2,4-) 95-63-6	5190	NA	Irritation of skin, eyes, nose, throat, bronchitis, anemia, drowsiness, fatigue, nausea	Eyes, skin, RS, CNS, blood	MEG based on Csat. At this level, inhalation is the most probable route of exposure. Refer to 1-year Air-MEG.
Trimethylbenzene (1,3,5-) 108-67-8	5190	NA	Irritation of skin, eyes, nose, throat, bronchitis, anemia, drowsiness, fatigue, nausea	Eyes, skin, respiratory system, CNS, Blood	MEG based on Csat. At this level, inhalation is the most probable route of exposure. Refer to 1-year Air-MEG.
Vanadium 7440-62-2	1600	NA	Vanadium salts can cause abdominal cramping, diarrhea, black stools, and green tongue; bone marrow depression leading to changes in numbers of white and red blood cells. High concentrations can cause tremors, headache, and tinnitus. Irregular or slow heartbeat, kidney damage.	Kidneys, CNS, HEM	Metallic vanadium has low oral toxicity. It is ubiquitous in soils and approximately 20 ?gs are normally ingested daily. However, ingestion of 60-120 mg of a vanadium salt may be fatal. Pentavalent forms and vanadates are the most toxic. The effects shown in the table are primarily those of vanadium salts.
VX 50782-69-9	0.079	NA	Nausea, vomiting, diarrhea, abdominal cramps, headache, giddiness, dizziness, excessive salivation, tearing, miosis, blurred or dim vision, miosis, difficulty breathing, cardiac arrhythmias, loss of muscle coordination, muscle twitching, random jerking movements, convulsions, coma.	CNS, ChE Inh	See Table C-1 for additional info

Chemical CAS No.	1-yr soil MEG (mg/kg)	Cancer Class	Potential Symptoms †	Target Organs and Systems	Notes §
Xylene 1330-20-7	210	D	Headache, weakness, dizziness, confusion, nausea, vomiting, abdominal pain, shivering, incoordination, loss of appetite, tremors, disturbed vision, salivation, and difficulty breathing; liver and kidney damage, and cardiac arrhythmias are possible.	CNS, liver, kidneys, blood, GI tract	MEG based on Csat. At this level, inhalation is the most probable route of exposure. Refer to 1-year Air-MEG.
Zinc 7646-85-7	69000	D	Severe stomach irritation, nausea, vomiting, and diarrhea (for zinc chloride).	GI tract	

Footnotes on next page.

FOOTNOTES FOR TABLE E-1 SOIL-MEG VALUES

§ This column shows oral doses that have been estimated to cause the indicated toxic effects. The term BW was added to reported doses to differentiate between mg/kg of BW (70 kg) and mg/kg soil as shown in the "MEG" Column. Chemicals that can be absorbed through the skin are also noted in this column. Unless otherwise noted, any dermal toxicity listed in this column is based on acute dermal exposures. Estimated lethal doses and approximate toxic effect levels were obtained from the TOMES database software system, from Gosselin, et al (1976), from Hayes, *Pesticides Studies in Man*, and from the USEPA Health Advisory Source documents. Information on health effects resulting from dermal exposure was obtained from the TOMES database (intranet/DVD version; expires January 2000), see RD230.

Csat – Soil saturation concentration, the highest concentration expected in soil due to the volatility of the substance.
CHID – Chemical Hazard Information for Deployments. Additional Fact Sheet information is under development for notated Chemicals..
BW – Body weight
EEG – electroencephalogram (brain waves)
LC_{Lo} – Lethal Concentration – low (estimate of small percentage (e.g. 1-5 %) exposed will succumb lethally
MRL – Minimum Risk Level
NA – Not Available;
PAH – Polycyclic Aromatic Hydrocarbon

TABLE 2-4-1. TARGET ORGANS

TARGET ORGANS	
Eyes	Brain
Skin	Heart
Blood	Pancreas
Bladder	Adrenal Glands
Thyroid	Lungs
Bone	Liver
Fetus	Kidneys
Spleen	

TABLE 2-4-2. TARGET SYSTEMS

TARGET SYSTEMS	
CNS – Central Nervous System	CVS – Cardiovascular System
PNS – Peripheral Nervous System	ChE Inh – Cholinesterase Inhibitor
GI tract – Gastrointestinal Tract	UT – Urogenital Tract
RS – Respiratory System	CRC – Circulatory System
LRS – Lower Respiratory System	IMM – Immune System
URS – Upper Respiratory System	REPR – Reproductive System
ENDO – Endocrine System	HEM – Hemopoietic System
LYMP – Lymphatic System	

Units used:
µg/kg = micrograms per kilogram = ppb = parts per billion
mg/kg = milligram per liter = ppm = part per million
mg/kg/day == milligram chemical per kilogram body weight (ingested) per day

Cancer Class Categories:
The scheme used by the USEPA for categorizing chemicals according to their carcinogenic potential is as follows (see Section 2.4.3):
Group A: Human carcinogen
Group B: Probable human carcinogen:
Group B1 - Limited evidence in epidemiological studies
Group B2 - Sufficient evidence from animal studies
Group C: Possible human carcinogen Limited evidence from animal studies and inadequate or no data in humans.
Group D: Not classifiable
Group E: No evidence of carcinogenicity

CHEMICAL INDEX (SOIL)

APPENDIX F

HYPOTHETICAL CASE STUDIES

The purpose of these hypothetical case studies is to illustrate how preventive medicine personnel can use the Military Exposure Guidelines (MEGs) as a tool to support operational risk management activities. These case studies are not designed to specifically represent real-life situations, but to demonstrate how, given certain information, the MEGs can be used in context with environmental data. The reference tables are provided as quick references for use during review of the case studies.

REFERENCE TABLES

CASE STUDIES

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TABLE F-1. EXAMPLE OEH CHEMICAL RISK ASSESSMENT SUMMARY TABLE

CHEMICAL HAZARD	HAZARD RANKING			OPERATIONAL RISK ESTIMATE		PREDICTED HEALTH OUTCOME		CONTROLS & NOTES
	HAZARD TYPE	HAZARD PROBABILITY	HAZARD SEVERITY	RISK LEVEL	CONFIDENCE	DURING DEPLOYMENT	AFTER DEPLOYMENT	
						Symptoms: Incidence:	Symptoms: Incidence:	

TABLE F-2. CHEMICAL HAZARD SEVERITY RANKING CHART FOR MILITARY DEPLOYMENTS

MAGNITUDE OF CHEMICAL CONCENTRATION	**WATER**	< MEG	= MEG that is not based on TB MED 577 (See Water Note)		= MEG that is based on TB MED 577 (See Water Note)	See Water Note	See Water Note
	SOIL	< MEG	= MEG (See Soil Note)		See Soil Note	See Soil Note	See Soil Note
	AIR	< 1-yr MEG or < 14-day MEG	= 1-yr MEG or = 14-day MEG but = 1 to 24-hr Min-MEGs	≥ 1-yr MEG or ≥14-day MEG but > 1 to 24-hr Min-MEGs	> 1-hr Min-MEG but ≤ 1-hr Sig-MEG	>1-hr Sig-MEG but = 1-hr Sev-MEG	> 1 hr Sev-MEG
IN GENERAL, THE ASSOCIATED HEALTH OUTCOME ATTRIBUTIBLE TO EXPOSURE (Percentages are very uncertain and will vary by chemical and other confounding factors.)		No cases of illness or non-cancer disease and less than 1 cancer case in 10,000	0 – 10 % of personnel may develop illness or chronic disease	0 – 10 % of personnel may develop mild illness or temporary irritation	> 10 % of personnel may experience mild illness, irritation AND 0 – 10 % of personnel may develop more severe illness that begins to impair functional abilities.	10 – 25 % of personnel may experience severe illness or irritation and more noticeable degradation of performance capabilities AND Other personnel will, at least, suffer some mild effects	> 25 % of personnel may experience severe, incapacitating effects AND Fatalities will begin to occur just above the Sev Air-MEG with increasing number of fatalities as concentrations increase
ONSET OF SYMPTOMS		After the Mission		During the Mission			
HAZARD SEVERITY RANK		NONE	NEGLIGIBLE		MARGINAL	CRITICAL	CATASTROPHIC
HAZARD TYPE		NO HEALTH THREAT	HEALTH THREAT		MEDICAL THREAT		

WATER NOTE: Concentrations greater than the MEG *may* result in Hazard Severity from Marginal to Catastrophic if certain chemicals are present in high enough quantities and there is sufficient consumption. Additional information in the Notes column of the MEG Tables should be evaluated regarding impacts of higher levels of exposure.

SOIL NOTE: Soil is unlikely to represent a hazard that would yield a Medical Threat. Additional information in the Notes column of the MEG Tables should be evaluated for data regarding higher levels of exposure.

TABLE F-3. CHEMICAL HAZARD PROBABILITY RANKING CHART FOR MILITARY DEPLOYMENTS

PERCENT OF PERSONNEL THAT WILL EXPERIENCE EXPOSURES TO CONCENTRATIONS EQUAL TO OR GREATER THAN THE MEG*				
<10%	10<25 %	25<50 %	50<75 %	>75 %
Unlikely	Seldom	Occasional	Likely	Frequent

*Determination of the percent of personnel exposed to a chemical or mixture specifically above a guideline level can be based on modeling, gridding, or generalized assumptions.

TABLE F-4. RISK ASSESSMENT MATRIX (FM 100-14)

HAZARD SEVERITY		HAZARD PROBABILITY				
		Frequent (A)	Likely (B)	Occasional (C)	Seldom (D)	Unlikely (E)
		?	**?**	**?**	**?**	**?**
Catastrophic (I)	**?**	Extremely High	Extremely High	High	High	Moderate
Critical (II)	**?**	Extremely High	High	High	Moderate	Low
Marginal (III)	**?**	High	Moderate	Moderate	Low	Low
Negligible (IV)	**?**	Moderate	Low	Low	Low	Low
		RISK ESTIMATE				

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CS-1 Wartime Chlorine Plume

MISSION AND ENVIRONMENTAL SETTING

You are the preventive medicine officer located at a central base camp during a wartime mission in Central America. Your responsibilities include transferring information to/from the field units in your area and making recommendations to higher headquarters. You have just received intelligence information about a factory located in proximity to one of your units.

PART A - INITIAL RISK ASSESSMENT

A-1. HAZARD IDENTIFICATION

Step A-1.1. METT-TC: Chemicals, Media, and Locations

The intelligence information includes the following:

- Various chemicals are stored at the factory; of particular concern is chlorine.
- Large amounts (tons) are stored, but it appears the plant is not operational.
- Enemy troops are aware of the unit's location.
- The mission of the at-risk unit requires it to continue maneuvering near (within 1 mile of the facility) and then beyond the chemical factory.
- Light winds are blowing toward the at-risk unit.

You realize that the stored chlorine could be used purposefully against U.S. personnel through bombing or other mechanisms resulting in the release of chlorine. If a chlorine-plume were to drift downwind toward the unit, then the troops would be exposed. The primary exposure routes of concern are inhalation and direct contact with the eyes and skin. You check the Air-MEG tables and establish the health effects associated with acute airborne/inhalation exposures to chlorine:

- Burning of eyes, nose, mouth, and respiratory system
- Excessive tearing, runny nose
- Coughing, choking, chest pain
- Nausea, vomiting
- Hypoxemia, dermatitis

You need to notify the unit of the situation. You realize that the commanding officer will want some initial description of the type of threat posed by this hazard.

Step A-1.2. Preliminary Threat Analysis

Currently, you have limited information as to both the anticipated concentrations (severity of hazard) as well as the probability that a release would even occur. Because of the known presence of the chemicals and the possibility of a release (accidental or purposeful), you notify your commander that such a chlorine plume would be a HEALTH THREAT to unit personnel and should be considered a possible MEDICAL

THREAT that could result in the degradation of the unit's capacity to accomplish their mission. You indicate that this is based on limited information and wish to validate this threat level by performing a risk assessment. Your commander indicates that there is limited time available but that if a Risk Level could be provided it would facilitate better Risk Management decisions such as whether this warrants moving unit locations.

A-2. HAZARD ASSESSMENT

You realize that plume concentration levels and locations after a release could be estimated with air dispersion models and that this would provide a more realistic basis for your assessment of associated risks. You don't have the capability to run such a model, however, and coordination with agencies such as USACHPPM, that do perform such tasks, will take more time than you have. So, even without quantitative data, you proceed through the risk assessment process based on the available information.

Step A-2.1. Hazard Severity Evaluation

Estimating hazard severity is particularly difficult in this situation. An explosion would very likely release a large amount of chlorine, but the amount of dissipation in the environment before reaching the unit is unknown. Based on the information in Appendix C, chlorine only has short-term Air-MEG and, therefore, it should be considered more of an immediate, acute hazard.

From the information in Appendix C, you decide that a chlorine plume can be quite dangerous and that exposures could significantly degrade the unit with the acute symptoms identified in Step A-1.1, or cause the unit to be completely disabled with the possibility of deaths. Therefore, you decide to conservatively estimate a severity range of CRITICAL to CATASTROPHIC.

Step A-2.2. Hazard Probability Evaluation

Available intelligence reports tell you that the enemy has the means and will to destroy the factory. Due to this battlefield environment, the S2 estimates that the probability of the enemy attacking the facility resulting in a chlorine-plume in the direction of the unit as likely. Based on this estimate, you predict that 50-75% of the unit could be exposed to chloride concentrations greater than the MEG, resulting in a hazard probability rank of LIKELY.

Step A-2.3. Risk Characterization

Table 1-A provides the risk characterization summary.

A-2.3.1 Risk Estimate

The above hazard rankings combine to present an operational risk of HIGH to EXTREMELY HIGH. This risk level forecasts a unit status of Red (Combat Ineffective) to Black (Requires Reconstitution), if the Command bases its decision framework on FM 101-5-1.

A-2.3.2 Confidence Level

You consider your confidence in the risk estimate to be LOW. This is based on the following attributes of the available information:

- Whether the enemy will sabotage the facility while the unit passes by is not known.
- If the factory is sabotaged, then the resulting chlorine concentrations in the plume cannot be predicted, as the size of the release and local climatic conditions will influence any exposures

?? A chlorine-plume scenario is plausible and the immediate health effects of excessive chlorine exposures are well known.

A-2.3.3 Threat Category

During Hazard Identification, you estimated that such a chlorine plume would be a health threat to unit personnel and should be considered a possible medical threat that could result in the degradation of the unit's capacity to accomplish their mission. During the Hazard Assessment, you based the hazard severity estimate of critical to catastrophic on the fact that a chlorine-plume can be quite dangerous and exposures could significantly degrade the unit with acute symptoms that render them incapacitated.

Therefore, according to guidance in the Chemical Hazard Severity Chart on Table F-2, you conclude that the threat category should be increased to a MEDICAL THREAT.

A-3. DEVELOP AND COMPARE CONTROLS FOR COA DEVELOPMENT

You notify the unit of your assessment and verify the unit's exact location and number of personnel. The only control available is to have the unit relocate. If the unit relocates far enough away from the downwind side of the facility, then the hazard is eliminated. A decision is made by the unit commander to have the unit relocate further away until further notice.

PART B - RE-ASSESSMENT OF RISK

B-1. HAZARD IDENTIFICATION

Step B-1.1. METT-TC: Chemicals, Media, and Locations

A short time later, you receive word that during the retreat back to base camp, the factory was bombed. Personnel had already moved away from the downwind side of the factory approximately one-half mile when the incident occurred. The commander of the unit has halted movement and is considering if the unit should prepare to turn back. The success of the mission requires movement forward, and since the hazard (the stored chlorine tanks) has been mitigated somewhat, and because an immediate, quick movement through the area may be unexpected, it would be an opportune time to proceed. You can appreciate the strategic benefits to this plan but caution the commander that residual contamination might present a hazard.

Step B-1.2. Revised Threat Analysis

You inform the commander that without information regarding dispersion and evaporation of the chlorine, residual air contamination may still be able to cause health effects that degrade personnel performance. As a result you still consider the hazard to be present, and consider this a HEALTH THREAT, with potential to be a MEDICAL THREAT.

B-2. HAZARD ASSESSMENT

The commander informs you that he has already dispatched a member of his unit with sampling equipment and protective gear to obtain real-time data from the area. A few minutes later this individual reports back via radio and states that air levels of chlorine are averaging about 4 ppm (10 mg/m^3).

Step B-2.1. Hazard Severity Evaluation

You check Appendix C and determine this to be just above the 1-hour significant-effect Air-MEG (2 ppm), and well below the severe-effect level 1-hour Air-MEG (22 ppm). Based on the suggested guidance in the Chemical Hazard Severity Ranking Chart in Table F-2, the hazard severity associated with measured concentrations greater than a Significant 1-hr MEG should be considered CRITICAL. The 1-hr significant MEG defines a "threshold" level for irreversible, permanent, or serious health effects that may result in performance degradation and incapacitate a small portion of individuals. Since the detected level (4 ppm) is substantially below the severe health effects MEG (22 ppm), you expect that a relatively small number of personnel would actually be affected to the point of more noticeable performance degradation, which may prevent them from quick maneuvering through the area.

Due to the small portion of the unit that you would expect to be affected significantly and the likely possibility that chlorine levels will likely be lower by the time personnel arrive at the area, you downgrade the severity rank from CRITICAL to MARGINAL, on the basis of professional judgment. In addition, dissipation of chlorine may bring the concentrations to levels less than the 1 hr Significant Air-MEG.

Step B-2.2. Hazard Probability Evaluation

You conclude that the probability of exposure to levels measured by the unit's reconnaissance will be LIKELY to OCCASIONAL while the unit passes through the area.

You did not select frequent because the Air-MEGs are for 1-hour average concentrations, not single grab samples (as was collected) and dissipation of the plume should continue.

Note: Such a decision must be based on professional judgment on a case-by-case basis. Dissipation of airborne chemicals is highly dependant upon the chemical in question, weather, terrain, and other site considerations.

Step B-2.3. Risk Characterization

Table 1-B provides the risk characterization summary.

B-2.3.1. Risk Estimate

The above hazard rankings combine to present an operational risk of MODERATE. This risk level forecasts a unit status of Amber (Mission Capable, with minor deficiencies), if the Command bases its decision framework on FM 100-14 and FM 101-5-1.

B-2.3.2. Confidence Level

You consider your confidence in the risk estimate to be MEDIUM; that is, for a chemical risk assessment, relatively high level of confidence.

Note: There are very few situations where a High degree of confidence would be reported due to the inherent limitations of our knowledge and simplistic assumptions of exposure processes and

toxicological/physiological/pharmocokinetic processes. For this assessment the degree of confidence is based on the following attributes of the available information:

?? Because the field measurement equipment is fairly accurate, data are considered good. However, the instrumentation is giving only a single point-in-time reference – the true levels that personnel would be exposed to are very possibly much less depending on time they take to get there and the meteorological conditions that impact the rate of chlorine dissipation.

?? Though not as weakly supported as some chemicals, the human toxicity estimates for chlorine have several uncertainties associated with them, usually addressed by safety factors or some degree of built-in conservatism.

B-2.3.3. Threat Category

The unit will be moving through the area of concern rapidly, which may mean less than a full hour of exposure, but there will be heavy exertion and increased breathing involved. At the detected levels, health effects are expected to be noticeable and in a small portion of the unit may be severe enough to significantly degrade performance abilities. The effects may continue after the exposure is eliminated. As such, as previous conclusion that the chlorine plume is a MEDICAL THREAT remains unchanged.

B-3. DEVELOP CONTROLS AND ASSESS RESIDUAL RISKS

Step B-3.1. Develop Controls

You discuss options with the unit commander. This includes:

1. No action and risk re-assessment at a later point in time with reanalysis;
2. Use of an alternate route circumventing the area of concern;
3. Use of the planned route using protective gear for personnel as they move through the area; or
4. Use of the planned route without protections; accepting the risk of health effects for within the unit.

Step B-3.2. Residual Risks

The commander considers risks associated with these options. Option 1 poses other risks because of the delayed time in an unsafe environment where enemy ambush is plausible. Option 2 has similar disadvantages because extending the mission with delays would also drain supplies/resources. For Option 3 to be viable, full-faced chemical-cartridge respirators (with chlorine cartridges) would need to be supplied immediately to the unit. This would not be possible due to the nature and location of the unit's operation. Additionally, such protective gear would inhibit movement, reduce visibility and communication capabilities, add to overall fatigue, and pose potential heat stress hazards. Choosing Option 4 would be an acceptance of the health and operational risks defined earlier. If the commander selects this option, then he/she must communicate this risk to his soldiers.

Step B-3.3. Actions to Increase Confidence in Risk Estimate

Because of the tactical necessity for making a quick decision, time does not allow for additional analyses to increase confidence in the analysis. No confidence-increasing actions are, therefore, recommended.

TABLE 1-A. PART A RISK ASSESSMENT SUMMARY AND RECOMMENDED CONTROLS

CHEMICAL HAZARD	HAZARD RANKING			OPERATIONAL RISK ESTIMATE		PREDICTED HEALTH OUTCOME		CONTROLS & NOTES
	HAZARD TYPE	HAZARD PROBABILITY	HAZARD SEVERITY	RISK LEVEL	CONFIDENCE	DURING DEPLOYMENT	AFTER DEPLOYMENT	
Possible Chlorine Plume	Medical Threat	Likely	Critical to Catastrophic	High to Extremely High	Low	Symptoms: Burning of eyes, nose, mouth, and respiratory system; excessive tearing, runny nose; coughing, choking, chest pain; nausea, vomiting; hypoxemia, dermatitis Incidence: 10-25%	Symptoms: Uncertain Incidence: Uncertain	Relocate Unit or No Action

TABLE 1-B. PART B RISK ASSESSMENT SUMMARY AND RECOMMENDED CONTROLS

CHEMICAL HAZARD	HAZARD RANKING			OPERATIONAL RISK ESTIMATE		PREDICTED HEALTH OUTCOME		CONTROLS & NOTES
	HAZARD TYPE	HAZARD PROBABILITY	HAZARD SEVERITY	RISK LEVEL	CONFIDENCE	DURING DEPLOYMENT	AFTER DEPLOYMENT	
Dissipating Chlorine Plume	Medical Threat	Likely to Occasional	Marginal	Moderate	Medium	Symptoms: Same as above, but should be less severe Incidence: 0-25%	Symptoms: Uncertain Incidence: Uncertain	1. Wait longer 2. Alternate route 3. Move out with PPE 4. Accept risk and move out

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CS-2 Cyanide in Proposed Water Supply

MISSION AND ENVIRONMENTAL SETTING

You are deployed very early in a peacekeeping operation. Base campsites are being selected and evaluated for follow-on forces as the mission expands. Planners have selected a location for a large base camp near a small city which has a municipal water supply. Logisticians want to use that municipal supply as a source of drinking water for the camp without having to rely on treatment by Army Reverse Osmosis Water Purification Unit (ROWPU) technology.

The test strip from your Water Quality Analysis Set – Preventive Medicine (WQAS-PM) indicates the presence of cyanide at concentrations around 4 milligrams per liter (mg/L). No other contaminants of concern were identified. The source of cyanide could be the deliberate use of hydrogen cyanide in the water as a chemical weapon, or the source could be one of several industries in the area.

1. HAZARD IDENTIFICATION

Step 1.1. METT-TC: Chemicals, Media, and Locations

Intelligence has indicated that the enemy has the capability to use cyanide as a chemical weapon and the municipal water supply is accessible. The municipal water supply has been abandoned and few industries in the area are operational. There are several industries in the vicinity that could have contaminated the surface water used by the municipal source.

Step 1.2. Preliminary Threat Analysis

Based on the peacekeeping operation, the mission may require the length of deployment to extend from 6-months to 1-year for personnel. The climate of the area fluctuates significantly throughout the year and reaches extreme temperatures in the summer months. Since personnel activities may require long work-shifts during the day when temperatures are extreme, you assume that many personnel will consume up to 15 L of water per day (per standard assumption pertaining to military personnel water consumption in TB MED 577).

You refer to the MEGs for cyanide in Appendix D (summarized below in Table 2-A). Guidelines are available for both temperate and arid climates for which standard practice are associated with assumptions of 5L/day and 15 L/day, respectively. Though several different exposure durations are represented, you note that the MEGs are the same for both short- and long-term durations. You also note, from the "Chemical" column of the table in Appendix D, that the MEGs for cyanide are actually TB MED 577 standards.

TABLE 2-A. MILITARY EXPOSURE GUIDELINES FOR CYANIDE IN WATER

Consumption Rate	5-day MEG (mg/L)	2-week MEG (mg/L)	1-year MEG (mg/L)
5 L/day	6	6	6
15 L/day	2	2	2

Since the detected concentration of 4 mg/L exceeds the 15 L/day cyanide drinking water MEG/TB MED 577 standard, as your preliminary threat analysis you determine that personnel exposure to cyanide from the municipal water supply is a HEALTH THREAT. You are not sure if the health effects would be significant enough to result in a medical threat. You notify your commander of the situation and that you are in the process of more specifically assessing the risks.

2. HAZARD ASSESSMENT

Step 2.1. Hazard Severity Evaluation

You have already established that the detected concentration of cyanide exceeds the 15 L/day MEG/TB MED 577 standard below which deployed military personnel drinking the municipal water should experience no adverse health effects for up to 1-year of consumption, assuming no other contamination and no increase in the cyanide concentration. You get more details by referring to the "Notes" column of Appendix D or the TB MED 577. The additional information from the "Notes" includes information regarding various concentrations of cyanide. This information is summarized below in Table 2-B.

TABLE 2-B. HEALTH EFFECTS FROM INGESTION OF CYANIDE IN DRINKING WATER

Consumption Rate	Safe Water Concentration (mg/L)	Changes in Blood Chemistry but no Clinical Effects (mg/L)	Metabolic Acidosis with Reversible Symptoms * (mg/L)	Life-threatening Toxicity (mg/L)
5 L/day	0-6	12-24	24-48	48+
15 L/day	0-2	4-8	8-16	16+

* For example: severe headaches, weakness, palpitation, nausea, giddiness and tremors.

Based on the Chemical Hazard Severity Ranking Chart for Military Deployments in Table F-2, the severity of cyanide exposures at concentrations around 4 mg/L for personnel consuming 15L/day is suggested to be Marginal, in part because this is a TB MED 577 standard which was developed using less conservative interpretations of toxicity information that other MEGs. The Marginal category is associated with personnel with mild effects and a few developing more significant effects that begin to impair functional abilities. According to the additional information summarized above, you feel confident that at 4 mg/L, the effects caused by cyanide would not be noticeable to personnel and, therefore, would *not* be expected to degrade performance capabilities or impact the mission. In addition, there are no long-term or delayed effects associated with the hazard. So a Marginal severity seems overly conservative. But you do note that the sampling was limited and that there is a possibility that concentrations could at times be greater than 4 mg/L. Since even short-term consumption at levels of around 8 mg/L could cause significant (performance-degrading effects), you decide to conservatively categorize the hazard severity as MARGINAL.

Step 2.2. Hazard Probability Evaluation

Without continuous monitoring, there is no way to know if the cyanide levels will fluctuate over time or what the magnitude of the fluctuations would be. Since there is only one source of drinking water available, you assume all deployed military personnel will be exposed to cyanide. You also still think it

is reasonable to assume that most personnel will be conducting activities resulting in consumption rates greater than 5 L/day, so use of the 15 L/day MEG is an appropriate reference.

Based on the Chemical Hazard Probability Ranking Chart in Table F-3, you categorize the probability of personnel exposure above the 15 L/day MEG to cyanide in drinking water as FREQUENT (i.e., you assume greater than 75% of unit will be exposed at these levels and consume water at this rate, especially for durations for as little as 5 days).

Step 2.3. Risk Characterization

Table 2-C provides the risk characterization summary.

2.3.1. Risk Estimate

Based on your classification of the cyanide hazard severity and probability, you determine the overall risk level by using the Risk Assessment Matrix in Table F-4. Based on the hazard probability and severity rankings, the overall Risk Level is HIGH. In addition to the Risk Level, you must qualify how confident you are with this characterization and the associated mission impact, including a final classification of the overall type of Threat presented by this hazard.

2.3.2. Confidence Level

There are significant uncertainties associated with this risk estimate due to the lack of complete sampling data and information available. Sources of uncertainty in this case study include:

- Reliability of sampling results/potential variability of concentrations over time,
- uncertainties associated with toxicity information for cyanide
- estimates of personnel exposures and activities, and
- estimates of health effects resulting from personnel exposures.

The lack of additional and accurate sampling for cyanide in the municipal water supply contributes most heavily of these uncertainties and as a result the overall confidence in the risk level estimate is LOW.

2.3.3. Threat Category

The presence of cyanide in the selected drinking water supply source presents a HIGH operational risk which, according to FM 100-14, corresponds to an amber unit status and is expected to significantly degrade mission capabilities if the hazards occur during the mission. This assessment is given low confidence however, with error directed and being conservatively safe/protective of personnel health. Specifically, since only non-clinical health effects are expected at the detected cyanide level, degradation of personnel capabilities is not likely. However, the data indicate that levels do exceed an actual TB MED 577 standard that - according to doctrine - cannot be exceeded. In addition, since cyanide has the potential to render unit combat or mission ineffective if concentrations increase even slightly (and since you don't have enough data to suggest that this is not the case) you consider the threat category as a HEALTH THREAT with potential to be a MEDICAL THREAT.

3. DEVELOP AND COMPARE CONTROLS FOR COA DEVELOPMENT

Step 3.1. Hazard Controls

You note that cyanide cannot be removed from water by Army ROWPU technology. So, given the potential level of risk, you determine that, if possible, an alternative source of drinking water should be

sought. If this is not feasible, the current source should be continuously/frequently monitored to ensure levels are maintained or diminished. This can be easily done with test strips. In addition, since your assessment was conducted very early on in the peacekeeping operation, it is advised that samples be sent offsite to the lab for a more thorough analysis.

Other control options include considering a protected water supply, such as a new well drilled by the Corps of Engineers and dedicated to your planned base camp, with well water treated by appropriate technology, or obtaining supplied bottled water. A final option is to investigate the potential sources of contamination to better predict fluctuations in concentrations and possibly terminating any ongoing contamination. In addition to monitoring, the municipal water supply should be guarded to ensure that intentional contamination of the source does not occur.

Step 3.2. Residual Risk

Obtaining a new water source (e.g., certified bottled drinking water) would effectively take care of the identified hazard and eliminate associated risk. Alternatively, with continuous monitoring of the municipal water supply and investigation of potential cyanide sources, fluctuations in cyanide concentrations can be determined. If this additional data indicate that cyanide levels decrease to average levels below 2 mg/L, the threat would either be eliminated (NO THREAT) or at least reduced to a NEGLIGIBLE severity, resulting in a LOW risk. However, if monitoring indicates that concentrations increase to a level greater than 8 mg/L, the overall risk level of HIGH would be confirmed with greater confidence or possibly increase to EXTREMELY HIGH. At levels greater than 8 mg/L the effects to personnel would increase and overall unit mission capability would be significantly diminished to the point of being combat ineffective.

Step 3.3. Actions to Increase Confidence in Risk Estimate

Continuous monitoring will improve estimates of fluctuations of cyanide concentrations in the water supply. In addition, identifying the source(s) of contamination will aid in this determination. Better estimation of concentrations will result in more accurate assessments of personnel exposures and increase the confidence level to MEDIUM.

TABLE 2-C. CYANIDE IN DRINKING WATER: RISK ASSESSMENT SUMMARY AND RECOMMENDED CONTROLS

CHEMICAL HAZARD	HAZARD RANKING			OPERATIONAL RISK ESTIMATE		PREDICTED HEALTH OUTCOME		CONTROLS & NOTES
	HAZARD TYPE	HAZARD PROBABILITY	HAZARD SEVERITY	RISK LEVEL	CONFIDENCE	DURING DEPLOYMENT	AFTER DEPLOYMENT	
Cyanide in drinking water with consumption rates at 15 L per day	Health Threat, potential Medical Threat	Frequent	Marginal	High	Low	Symptoms: No clinical symptoms to possible headache, breathlessness, weakness, palpitation, nausea, and others Incidence: ~10%	Symptoms: uncertain Incidence:	Alternate drinking water source and/or additional analysis of water

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CS-3 Peacekeeping Site Reconnaissance

MISSION AND ENVIRONMENTAL SETTING

You are deployed on a peacekeeping mission near the southern tip of South America. You accompany an infantry company that will be performing a border reconnaissance/security mission. It is undetermined at this time how long the mission will last, although approximately 2 weeks is anticipated. A temporary base camp must be established for the reconnaissance team. "Site X" is determined to be a particularly ideal location. Part of the mission is to evaluate its suitability as a more permanent base camp for future activities that could last up to one year in duration.

Your preventive medicine responsibilities require you to assess the potential health threats to the military personnel from environmental chemicals that may be present at Site X. The team is carrying limited supplies in order to maneuver quickly. This includes three days of drinking water.

Your task is twofold:

1. Assess the OEH hazards posed to the members of the reconnaissance mission.
2. Assess and determine health threats to other personnel who may eventually be sent to the area for long-term (base-camp) deployment status.

The commanding officer will balance health risks with other risks such as logistical obstacles and physical hazards in order to make appropriate operational decisions regarding the reconnaissance mission, as well as for future deployments into the area.

PART A - INITIAL RISK ASSESSMENT

A-1. HAZARD IDENTIFICATION

Step A-1.1. METT-TC: Chemicals, Media, and Locations

You consider all general information immediately available. Site X is five acres in size and is near a small town. There are some indications of industrial activity including two abandoned structures. You notice a slight aromatic odor around the side of one structure. A municipal water supply is identified in one of the structures; however, a member of the reconnaissance team tasted the water and noted that it had a slight fuel-like taste, although there is no odor.

Note: Tasting of water sources without knowing that they are safe is NOT recommended. However, individuals ignorant of this rule of thumb are sometimes known to taste untested water. If this happens, that information can be useful. Such "sampling" of water sources should be avoided.

Using the kits in your Water Quality Analysis Set-Preventive Medicine (WQAS-PM), you check the identified water supply in accordance with TB MED 577 (*Sanitary Control and Surveillance of Field Water Supplies*). You determine that the physical and chemical properties measurable by the kits in your WQAS-PM meet the Tri-Service Standards listed in the Appendices of TB MED 577. Because of the

strange taste in the water, you collect three grab samples around noon on the first day. The water samples are sent to the supporting medical laboratory for rear-area analysis. The results may not be available for up to seven days.

Later in the afternoon, you obtain three, 1-hour air samples from around the site, locating two samples nearby the two structures in the camp and one sample in the middle of the camp away from the structures. You analyze them using your available field equipment.

No obvious spills are observed, so no surface soil samples are collected.

Step A-1.2. Preliminary Threat Analysis

(A) Water Hazards
The first reaction may be that since the water meets the Tri-Service Standards, there may be no direct Health Threats associated with drinking from the available water source. However, you note that the field kits do not provide a complete analysis, so the results of rear-area analysis may determine that the fuel-like taste may be from other contaminants not detected by your WQAS-PM kit that may pose health threats. In addition, due to the fuel-like taste personnel may drink less than optimum amounts of water, resulting in a dehydration hazard. You decide to inform your commander of the potential HEALTH THREAT. The commander decides that there is enough concern to warrant the acquisition of additional bottled water to be sent to the field team for the duration of the reconnaissance mission. Decisions regarding potential future use of the water source will be deferred pending receipt of rear-area results.

(B) Airborne Hazards
The air screening analysis identified the following compounds at the concentrations shown in Table 3-A along with the corresponding Air-MEGs.

TABLE 3-A. AIR DATA AND ASSOCIATED AIR-MEG VALUES

Chemical Detected	Site Air Concentrations (mg/m^3) *			Air-MEG Values (mg/m^3)			
	A Structure	B Structure	C Site center	1-hour (minimal)	8-hour	14-day	1-year
Acrylonitrile	0.01	0.02	0.01	22	4.4	0.22	0.11
Aldrin	0.21	0.20	0.009	25 **	0.25 [S]	0.006 [S]	0.00098 [S]
Benzene	202	32.0	2.0	160	1.6	0.16	0.039 [S]

* Data represent 1-hour averaging times.
** Value is the severe effect level because TG 230 provides no value for the 1-hour minimal and significant effect levels.
[S] Skin notation, dermal exposures have the potential for significant contribution to overall dose.

In addition to noting the MEG values, you check the type of health effects posed by acrylonitrile, aldrin, and benzene – and note that they all cause similar irritating and CNS effects and are classified as (Level

A-B) carcinogens. You decide to evaluate each chemical hazard separately first, but realize that multiple chemical hazards (particularly when they affect similar target organs/systems) may compound the overall health risk.

At a glance, you note that while acryonitrile was detected at each location, the concentrations were all below the MEGs, including the 1-year MEG. Therefore, you decide that the hazard from acryonitrile *alone* does not pose a health threat.

You now focus on the hazards presented by the other two chemicals, which have been detected above some of the associated MEGs. The following demonstrates your preliminary analysis of the threat posed by these air contaminants:

?? Aldrin: All concentrations are greater than the 14-day and 1-year MEGs, indicating that aldrin poses a potential HEALTH THREAT (though probably not a Medical Threat) to the reconnaissance team as well as for personnel in a future long-term base camp.

?? Benzene: Since all of the concentrations are greater than the 14-day and 1-year MEG, there may be some adverse health impacts associated with exposure to benzene at this site, and thus this presents a HEALTH THREAT. More importantly, one of the samples detected benzene at a 1-hour average concentration (202 mg/m^3) that is greater than the 1-hour minimal effects Air-MEG (160 mg/m^3), though it is less than the significant effects Air-MEG (479 mg/m^3). This could result in a MEDICAL THREAT in that noticeable effects may begin and a few personnel may experience some impairment/degradation of functional abilities.

You conclude that the benzene and aldrin together with the acrylonitrile are an airborne hazard that present a HEALTH THREAT (many personnel can be expected to have some irritation/discomfort, and there is potential for increased cancer risk) with potential to be a MEDICAL THREAT (irritation may become more severe along with headaches, nausea that could impair some personnel ability to function at 100% capability). You also note that the two samples nearest the structures (A and B) yield the highest concentrations and, thus, the vicinity around the structures appears to pose somewhat higher risk.

Since the greater threat is near the structures that are located to the east side of the site, you recommend to the commander that personnel locate activities upwind (north west) of the area. The commander agrees since the structures are not located in a critical area of the site and can be easily avoided. As a precaution, you post some warning flags near these areas.

A-2. HAZARD ASSESSMENT

Since your commander has instituted the controls necessary to eliminate one hazard to the reconnaissance team by acquiring bottled water for the duration of their mission and has mitigated an aspect of the airborne hazard, you focus on a more detailed assessment of the degree of risk posed to the recon and long-term personnel from airborne exposures around the central area of the site. Once you obtain the water analysis results you will re-assess the overall risk to long-term deployment personnel.

You begin your air hazard assessment by focusing on the primary hazards aldrin and benzene, although you keep in mind that the presence of acrylonitrile contributes to the hazard.

Step A-2.1. Hazard Severity Evaluation

You begin by re-evaluating the concentrations from Sample C and comparing to associated MEGs (see Table 3-B).

TABLE 3-B. RE-EVALUATION OF THREAT SEVERITY

Chemical	Concentration (from central area)	Air-MEG Values (mg/m^3)			
		1-hour (minimal)	8-hour	14-day	1-year
Aldrin	0.009 mg/m^3	25 **	0.25 [S]	0.006 [S]	0.00098 [S]
Benzene	2.0 mg/m^3	160	1.6	0.16	0.039 [S]

* Data represent 1-hour averaging times.
** Value is the severe effect level because TG 230 provides no value for the 1-hour minimal and significant effect levels.
[S] Skin notation, dermal exposures have the potential for significant contribution to overall dose.

(A) Aldrin
The concentration exceeds the 1-year MEG, but more importantly it exceeds the 14-day MEG. From the tables in Appendix C of TG 230, you note the types of symptoms caused by inhalation exposures to Aldrin above the 14-day MEG include the following, in order of increasing severity:

- Headache, dizziness
- Nausea, vomiting, malaise
- Limb jerks, convulsions
- Coma, hematuria (blood in urine), azotemia (excess of urea in blood due to kidney failure)

The 14-day MEG is defined as the airborne concentration for a continuous exposure for up to 14 days (24 hours/day) that should not impair performance and is considered protective against any significant, non-cancer effects. If soldiers experience aldrin exposures greater than the 14-day MEG, then performance degradation could result, or the potential for inducing delayed/permanent disease (e.g., kidney disease or cancer) increases.

You estimate that true exposures for individuals exceeding the MEG will only be slightly greater than the MEG. Therefore, the more serious symptoms listed above are not likely to occur. The most likely symptoms would be headache, dizziness, nausea, vomiting, and malaise. Based on the severity-ranking chart in Table F-2, these would be defined as "mild illness or temporary irritation" in a small portion (0-10%) of the exposed group. A hazard severity ranking of NEGLIGIBLE would, therefore, be indicated.

(B) Benzene
As with aldrin, the 1-year MEG is exceeded, but of greater importance in this case is that the 14-day and even 8-hour MEGs are exceeded. The types of symptoms caused by inhalation exposures to benzene above the 8-hour and 14-day MEG include the following in order of increasing severity:

- Eye, skin, nose, and respiratory irritation, headache

- ?? Nausea, loss of coordination, fatigue, lack of appetite, weakness, exhaustion, dermatitis
- ?? Bone marrow depression, cancer

If soldiers experience benzene exposures just greater than the 14-day MEG, then performance degradation could result, or the potential for inducing delayed/permanent disease (e.g., kidney disease or cancer) increases. If soldiers experience benzene exposures greater than the 8-hour MEG, then exposures could begin to produce mild, non-disabling, transient, reversible effects, if any. Such effects should not impair performance unless exposure concentrations begin to increase more, where performance degradation could result, especially for tasks requiring extreme mental/visual acuity or physical dexterity/strength.

You estimate that true exposures for individuals exceeding the 8-hour MEG will only be slightly greater than the MEG. Therefore, the more serious symptoms listed above are not expected to occur. The most likely symptoms would be headache, dizziness, nausea, vomiting, and malaise. Based on the severity-ranking chart in Table F-2, these would be defined as "mild illness or temporary irritation" in a small portion (0-10%) of the exposed group. A hazard severity ranking of NEGLIGIBLE would, therefore, be indicated.

(C) Multiple Chemical Interactions: You note the possible increase in type/severity of effects due to the combined effects of the mixture. Specifically, the presence of acrylonitrile and aldrin with benzene might increase the severity of skin irritation and increase risks of cancer. The true effects/severity of such a mixture are not known, however.

Step A-2.2. Hazard Probability Evaluation

The portion of the unit that may actually experience exposures greater than the 8-hour or 14-day MEG is a large unknown. You assume that all personnel (during both the reconnaissance mission as well as during long-term deployment at the base-camp) will be exposed to the air mixture of aldrin, benzene, and acrylonitrile each day. However, since personnel will be rotating duties for camp maintenance, meals, training and security duties, most personnel will be away from the camp regularly. Exposures to the chemical mixture will be somewhat intermittent during the deployment (both reconnaissance as well as base camp – although base-camp deployment will result in more consistent exposures).

(A) Aldrin

Reconnaissance Mission:
The 1-hour average concentration of aldrin at the site center was 0.009 mg/m^3, while the 14-day MEG is 0.006 mg/m^3. Due to the knowledge about the activity patterns of recon personnel over the course of their operation, you estimate that most reconnaissance personnel will not experience 14-day (24 hour/day) average exposures above the 14-day MEG of 0.006 mg/m^3. You therefore rank the aldrin hazard probability for the reconnaissance mission as OCCASIONAL, as remotely possible that personnel will experience exposures greater than 0.006 mg/m^3.

Base-Camp (long-term exposure):
For personnel stationed at a base-camp you also assess the probability that the 1-year (24-hr daily average) guideline will be exceeded. In this case, you think it is very possible that most personnel will be exposed to average daily concentrations through a year's time above the 1-year air MEG of 0.00098 mg/m^3. Therefore, you rank the probability of this long-term deployment hazard as FREQUENT.

(B) Benzene

The 1-hour average concentration of benzene at the site center was 2.0 mg/m^3, a concentration greater than the 1-year, 14-day MEG (0.16 mg/m^3) and the 8-hour MEG (1.6 mg/m^3). However, the concentration was much less than the 1-hour minimal-effect MEG of 160 mg/m^3. You focus your assessment on the most immediate hazard (shorter of the two exposure durations of concern (8-hrs)).

You estimate that most if not all personnel that remain at the camp during any given day (either during reconnaissance mission or long – term deployment at the base camp) will experience 8-hour average exposures greater than the 8-hour MEG. You therefore rank the benzene hazard probability for either deployment scenario as FREQUENT.

Step A-2.3. Risk Characterization

Table 3-C provides the risk characterization summary.

2.3.1. Risk Estimate

The above hazard rankings combine to present an overall operational risk of MODERATE. This risk level forecasts a unit status of Amber (Mission Capable, with minor deficiencies), if the Command bases its decision framework on FM 101-5-1.

2.3.2. Confidence Level

You consider your confidence in both of these risk estimates to be LOW. This is based, primarily on the following limitation of the assessment. Though the measured air concentration data are considered good because the field measurement equipment is fairly accurate, the number of samples is too small to provide a confident representation of true air concentrations over the course of a day and over the course of the two-week mission.

2.3.3. Threat Category

You determine that these airborne hazards pose a HEALTH THREAT, but not a Medical Threat to both the reconnaissance team as well as personnel stationed at the base camp.

A-3. DEVELOP AND COMPARE CONTROLS FOR COA DEVELOPMENT: RECON

Step A-3.1. Develop Controls

You discuss control action options that could reduce the overall MODERATE risk with the unit commander. These options include:

1. Accept the risk and remain at Site X, but monitor for symptoms consistent with benzene exposures. If effects emerge in the unit to unacceptable levels, then the commander will re-evaluate the situation.
2. Accept the risk temporarily and perform a risk re-assessment after another day with additional air data. You would continue air sampling to cover more of the site and several times in the day.
3. Relocate the personnel to an alternative camp.

(A) Reconnaissance Mission:
Because only the airborne exposures were of concern to the RECON mission and the risk level is Moderate, the need for controls is not deemed critical. The commander decides to accept the risks (chooses Option 1) posed during this short-term mission. He asks you to prepare a short briefing to notify personnel as well as medical staff and to ensure that the situation along with any identified health outcomes that could be associated with such exposures are properly documented.

(B) Base Camp (Long-Term) Deployment:
Pending the water analysis, you hold off determining control actions at this time.

Step A-3.2. Residual Risks
Since Option 1 was selected for the RECON mission, the residual risk would remain MODERATE.

Step A-3.3. Actions to Increase Confidence in Risk Estimate
In this case, the additional sampling (Option 2) would increase the overall confidence in you risk characterization.

PART B - RE-ASSESSMENT OF RISK

B-2. HAZARD ASSESSMENT

Thus far you have identified an airborne health threat of Moderate risk to personnel who may be sent to Site X for long-term deployment status. At this time, the results from the rear-area water analyses have arrived. You now need to consider how the hazards combined from air and water may contribute to overall Risk.

Data indicate that one chemical - benzene - was present in the water at an average concentration of 0.9 mg/L, with little variability in concentration. This is consistent with the taste threshold range of 0.5- 4.5 mg/L indicated in the TG 230 Table in Appendix D. You have determined that the MEGs for the 5 L/day consumption rate are most appropriate for this assessment because of the climate in this area of the world (i.e., southern tip of South America).

Step B-2.1. Hazard Severity Evaluation
The health effects of concern for benzene in water are vomiting, lightheadedness, headache, anemia and other effects. Longer-term effects include immuno-suppression, bone marrow suppression, and cancer, similar to the effects of air exposures. Since all the MEGs are designed represent a protective level for these effects, concentrations exceeding the MEGs indicate the potential for these effects to occur. The operational severity of health effects (including number of personnel affected) that may occur during the deployment cannot be directly estimated. While a strict interpretation of the TG 230 Suggested Severity Ranking Chart in Table F-2 indicates that the severity of an exceeding a (non-TB MED 577) Water MEG results in a NEGLIGIBLE degree of severity, you assume that since even 5 day and 14-day Water MEGs are exceeded for a situation that would involve much longer exposure, you decide to rank the severity as MARGINAL, with the possibility that the health effects amongst some personnel may be severe enough to result in performance degradation.

Step B-2.2. Hazard Probability Evaluation
You rank the benzene hazard probability in water, relative to the 1-year MEG (0.14 mg/L), as FREQUENT, because if this water source were to be used all soldiers would be exposed to such levels every day. Because the concentration is also greater than the 5 and 14-day (5 L/day) MEGs, which are both 0.3 mg/L, the hazard probability, relative to the short-term MEGs, is also FREQUENT.

Step B-2.3. Risk Characterization
Table 3-C provides the risk characterization summary.

B-2.3.1. Risk Estimate

The airborne hazards present a risk level of MODERATE, indicating a potential unit status of AMBER (Mission Capable, with minor deficiencies), if the command bases its decision framework on FM 101-5-1. The waterborne hazards present a HIGH risk, indicating a potential unit status of RED (Combat ineffective), if the Command bases its decision framework on FM 101-5-1.

B-2.3.2. Confidence Level

You consider your confidence in the risk estimates to be LOW. Though the measured air and water concentration data are considered good, the number of samples is too small to provide a confident representation of true air and water concentrations over the course of the course of the future deployment.

B-2.3.3. Threat Category

Your previous judgment that these airborne hazards pose a HEALTH THREAT, rather than a medical threat, should not change. The consumption of water from the supply at the site, poses a MEDICAL THREAT because of the potential for health effects that may degrade functional abilities of personnel.

B-3. DEVELOP AND COMPARE CONTROLS FOR COA DEVELOPMENT

Step B-3.1. Hazard Controls

Because the airborne hazards pose the same MODERATE risk level and additional data have not been collected, the same controls and residual risks identified for the reconnaissance team apply. After checking in Appendix G of TG 230 (Water Quality Information Paper IP-31-014), you determine that Reverse Osmosis (RO) Treatment is not generally very effective against industrial organics. Therefore you may not significantly reduce the benzene levels with a RO unit. As such, the only viable control action against this hazard would be to procure bottled water for consumption.

Step B-3.2. Residual Risks

Use of bottled water would eliminate the hazard. However, based on recent findings you have learned that certain in country bottled water batches have not been of acceptable standards – so some additional assessment of such a source would be advised.

Step B-3.3. Actions to Increase Confidence in Risk Estimate

Again, additional sampling to better characterize the ambient air and water supply could be recommended.

TABLE 3-C: AIR AND WATER RISK ASSESSMENT SUMMARY AND RECOMMENDED CONTROLS

CHEMICAL HAZARD	HAZARD RANKING			OPERATIONAL RISK ESTIMATE		PREDICTED HEALTH OUTCOME		CONTROLS & NOTES
	HAZARD TYPE	HAZARD PROBABILITY	HAZARD SEVERITY	RISK LEVEL	CONFIDENCE	DURING DEPLOYMENT	AFTER DEPLOYMENT	
Air	Health Threat	Frequent	Negligible	Moderate	Low	Symptoms: mild temporary respiratory/eye/ skin irritation, headache, nausea, malaise Incidence: <10%	Symptoms: increased cancer and leukemia risk; kidney disease Incidence: <10%	Modify activity patterns, PPE, increase awareness, develop contingency plan
Water	Potential Medical Threat	Frequent	Marginal	High	Low	Symptoms: temporary vomiting, lightheadedness, headache, anemia Incidence: <10%	Symptoms: Increased risk of immuno-suppression, bone marrow suppression, and cancer Incidence: <10%	Eliminate hazard – obtain alternate drinking water source (such as bottled water).

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CS-4 Drinking Water: Chemical Exposure and Dehydration

MISSION AND ENVIRONMENTAL SETTING

An early insertion team will carry hand-held water treatment devices into their phase of a deployment. They intend to use local surface waters as a source of drinking water for several weeks. The environment is temperate, but due to the expected exertion level, consumption rates of up to 15 L/day are expected.

1. HAZARD IDENTIFICATION

Step 1.1. METT-TC: Chemicals, Media, and Locations

You learn that the local surface waters intended for use are brackish and have chloride concentrations around 1200 mg/L. The planner for the early insertion operation wants to know if that will be a problem for his troops.

Step 1.2. Preliminary Threat Analysis

You refer to Appendix D. The Water-MEG for chloride indicates that deployed personnel can drink water every day with chloride concentrations up to 600 mg/L in any climate for up to two weeks. However, at this concentration, according to the notes in Appendix D, about 2% of personnel might refuse to drink the water based on poor taste and are at an increased risk of dehydration. At a concentration of 1000 mg/L it is estimated that 10% of personnel are at risk of dehydration. You know that chlorides produce a salty or metallic flavor in water that becomes greater with increasing chloride concentrations. You also note that the Water-MEG is followed by a single asterisk indicating that the guideline is from the Tri-Service Field Drinking Water Standards (TB MED 577). Since the detected concentrations are twice this level, chloride is considered a MEDICAL THREAT and is evaluated further.

2. HAZARD ASSESSMENT

Step 2.1. Hazard Severity Evaluation

You get more details by referring to the TB MED 577. The major health effect of concern resulting from chloride exposure is dehydration. Dehydration symptoms can include weariness, apathy, impaired coordination, delirium, and heat stroke. At the Tri-Service Standard of 600 mg/L, about 2% of deployed military personnel can be expected to decline to drink the water and to be at risk of dehydration. As chloride concentrations reach 900 mg/L, approximately 7% of the deployed force might refuse to drink the water and become susceptible to dehydration. At chloride concentrations around 1200 mg/L, about 18% of the deployed force might refuse to drink the water and become susceptible to dehydration. At chloride concentrations around 1500 mg/L, about 36% of the deployed force might refuse to drink the water. In addition, at concentrations above the TB MED standard, there is increasing risk that non-acclimated deployed military personnel might initially experience laxative effects. Since the surface waters contain 1200 mg/L of chloride, approximately 18% of the unit may resist drinking the water and will be susceptible to dehydration. Table 4-A summarizes the estimated impact of dehydration on personnel from increasing chloride concentrations in drinking water.

TABLE 4-A. ESTIMATED IMPACT OF DEHYDRATION ON MILITARY PERSONNEL WITH INCREASING CHLORIDE CONCENTRATIONS IN DRINKING WATER*

Chloride Concentration in Drinking Water (mg/L)	Estimated % of Personnel at Risk of Dehydration
0	0.1
300	0.5
600	2.1
900	6.9
1200	18
1500	36

* These estimated impacts of dehydration apply to any consumption rate

You refer to the Chemical Hazard Severity Ranking Chart in Table F-2 to determine the hazard severity posed by personnel exposure to 1200 mg/L of chloride in the drinking water. You note that approximately 18% of the unit is predicted to exhibit symptoms of dehydration. Dehydration can be considered a health effect ranging from mild illness and irritation to one that impairs functional abilities. The symptoms are expected to occur during the mission. In addition, some personnel may suffer from laxative effects or combined effects from heat stress. Therefore, the resulting hazard severity using this chart is classified as MARGINAL to CRITICAL.

Step 2.2. Hazard Probability Evaluation

Since the treated surface water will be the only source of drinking water, 100% of the unit will be exposed to chloride in the water. Estimated chloride concentrations are greater than the Water-MEG so it is also expected that 100% of the unit will be exposed to chloride levels greater than the guidance. By using the Chemical Hazard Probability Ranking Chart in Table F-3, the hazard probability should be considered FREQUENT.

Step 2.3. Risk Characterization

Table 4-B summarizes the risk characterization.

2.3.1. Risk Estimate

As indicated above, at 1200 mg/L of chloride, as much as 18% of the early insertion team may decline to drink the surface water because of poor taste. Those team members who find the taste too objectionable will probably begin to dehydrate if another source of fluid is not readily available. As their dehydration increases, their ability to perform will be at increasing risk of deterioration. The risk of heat stroke also increases, especially if the early insertion team has a high workload and team members are carrying heavy loads.

Using this information and your professional judgment regarding your situation, you consult with the Risk Assessment Matrix in Table F-4 to determine the overall risk posed by exposure to chloride in drinking water. Based on the hazard ranks in the previous two sections, the corresponding operational risk estimate is considered HIGH to EXTREMELY HIGH. According to FM 100-14, the defined

consequence for these risk levels is significant degradation of mission capabilities with unit at 50-69% strength or loss of ability to accomplish the mission with unit strength below 50%.

2.3.2. Confidence Level

The confidence in the overall risk estimate for personnel exposures to chloride in drinking water is categorized as MEDIUM based on applying the Risk Assessment Matrix in Table F-4. Although detailed information is lacking regarding true personnel activity patterns, water consumption was already assumed to be at a maximum consumption rate to represent a worst-case exposure scenario. The TB MED 577 provides well-known symptoms for dehydration and the health outcome is plausible. Uncertainties in the sampling data and estimates of concentrations limit the confidence of this risk estimate to medium. For instance, information was not provided on the sampling methods used or if other substances were sampled for in the surface waters.

2.3.3. Threat Category

Based in the hazard assessment, exposures to current estimated levels of chloride in drinking water pose an extremely high operational risk. This implies that exposures to chloride in the drinking water have the capability to render the unit ineffective and should be considered a MEDICAL THREAT to the mission.

3. DEVELOP AND COMPARE CONTROLS FOR COA DEVELOPMENT

Step 3.1. Hazard Controls

Based on the high to extremely high level of risk, you recommend to the mission planner that an alternate source of drinking water, such as bottled water, be supplied. If this is not feasible, the water consumption of every individual in the unit should be closely monitored in order to help identify individuals that may be at risk of dehydration and take action before they are seriously affected. A risk communication plan to educate personnel on the risks of dehydration prior to the mission may help to encourage personnel to consume adequate amounts of water.

Hand-held water treatment devices would not be sufficient to remove chlorides and treat the quantity of water needed for the deployment duration. A Reverse Osmosis Water Purification Unit (ROWPU) would be required to produce potable water from a brackish source. However, this is not a viable option for the early insertion team.

Step 3.2. Residual Risk

Providing an alternate source of water would alleviate the potential risk altogether. If the brackish surface water is used for drinking, careful monitoring and educating personnel on the risks of dehydration should help reduce the operational risk somewhat.

Step 3.3. Actions to Increase Confidence in Risk Estimate

Confirmation sampling of the surface water bodies for chloride and other potential contaminants would increase your confidence in the risk estimate. In addition, if the water were found to contain chloride at the levels that are expected, monitoring of personnel would provide real-time data to verify your estimate of operational risk.

TABLE 4-B. CHLORIDE IN DRINKING WATER: RISK ASSESSMENT SUMMARY AND RECOMMENDED CONTROLS

CHEMICAL HAZARD	HAZARD RANKING			OPERATIONAL RISK ESTIMATE		PREDICTED HEALTH OUTCOME		CONTROLS & NOTES
	HAZARD TYPE	HAZARD PROBABILITY	HAZARD SEVERITY	RISK LEVEL	CONFIDENCE	DURING DEPLOYMENT	AFTER DEPLOYMENT	
Chloride in Drinking Water	Medical Threat	Frequent	Marginal to Critical	High to Extremely High	Medium	Symptoms: weariness, apathy, impaired coordination, delirium, heat stroke Incidence: 18%	Symptoms: uncertain Incidence:	Alternate source of drinking water such as bottled water

CS-5 Assessing Base Camp Air Quality

MISSION AND ENVIRONMENTAL SETTING

You are assisting with setting up a temporary base camp to be used as a staging area for rotating Army National Guard (ARNG) units performing an OCONUS annual training (AT). Units will be located in this area for no more than two weeks at any one time. You notice some pollution emanating from an industrial area in the nearby city. The base camp itself is on part of an old mining facility, but there is no indication that the mining activities that occurred in the past will present any hazards to personnel deployed temporarily to the camp. In addition, intelligence reports indicate that sabotage to industrial operations in the nearby city is unlikely. The climate where the base camp is planned is categorized as temperate.

As part of your preventive medicine duties, you assist with monitoring and sampling procedures. You have been asked to obtain data on specific criteria air pollutants as is done in the U.S. to evaluate the overall quality of the air. In addition, you are assessing the potential for any adverse health effects for the personnel that are scheduled to establish the base camp and for the follow-up personnel that will use the camp. You have been instructed to limit your health effects assessment at this time to personnel with a maximum deployment of two weeks.

1. HAZARD IDENTIFICATION

Step 1.1. METT-TC: Chemicals, Media, and Locations

Only one day of air sampling was conducted for three different one-hour time periods during that day. All three of the samples were collected at the same location near the center of the base camp. Of the six criteria air pollutants sampled, only sulfur dioxide (SO_2) and particulate matter (PM_{10}) were detected. It surprises you that only SO_2 and PM_{10} were detected, because air pollution often consist of other associated pollutants. Nonetheless, you take the data that you have and move through the hazard identification process. Table 5-A presents the one-hour average concentrations for SO_2 and PM_{10}. Estimated daily average concentrations are also included on the table. You estimate daily average concentrations by assuming that each of the one-hour samples represents an equal portion of a day (8 hours). For example, you estimate the PM_{10} daily average by dividing the sum of 150 ?g/m^3, 400 ?g/m^3, and 254 ?g/m^3 by three. You recognize that you are introducing uncertainty by performing these calculations but would like to distinguish peak exposures from daily exposures.

TABLE 5-A. SAMPLE AND CALCULATED CONCENTRATIONS

	Sample 1 Time 0900-1000	Sample 2 Time 1200-1300	Sample 3 Time 2000-2100	Estimated Daily Average *
SO_2	0.4 mg/m^3	3.1 mg/m^3	0.5 mg/m^3	1.3 mg/m^3
PM_{10}	150 ?g/m^3	400 ?g/m^3	254 ?g/m^3	268 ?g/m^3

* The daily average was calculated by assuming that each individual, one-hour sample represented eight hours of the day. This assumption introduces uncertainty.

Step 1.2. Preliminary Threat Analysis

You know that after chemical hazards are detected, a judgment must be made as to the relative degree of health threat each hazard poses. The purpose is to limit the risk assessment to the hazards that pose credible health threats. The chemical hazards can be classified into health hazard categories (No Threat, Health Threat, and Medical Threat) based on a rapid comparison of a conservative estimate of the exposure point concentrations (i.e., maximum detected concentrations and/or average concentrations) to available standard military guidelines. The outcome of this step is described in the text below and shown in the Table 5-B.

For SO_2, the standard military guidelines that are available include the 1-hour Air-MEG Significant Effects Level, the 8-hour Air-MEG, and the 14-day Air-MEG. For PM_{10}, there currently are no Air-MEGs, but comparisons may be made to U.S. general population guidelines.

In order to classify the hazards, a general nature of the effects associated with exposures at, or near, the selected guideline must be known. The hazard identification is determined based on this information.

(A) SO_2

The 1-hour Air-MEG does not include a Minimal Effects Level. You note that the concentrations are less than the 1-hour Air-MEG Significant Effects Level and the 8-hour Air-MEG, but the sample taken between 1200 and 1300 has a concentration higher than the 14-day Air-MEG level. You realize that you may have "peaks" when the concentration is higher than the guideline, but on average you feel that the concentrations will be below the 14-day level. In fact, the estimated daily average concentration from the three sampling times (1.3 mg/m^3) is less than the 14-day guideline. You recognize, however, that the daily average concentration that you calculated is subject to uncertainty.

You read in the "Notes" column of Appendix C that SO_2 may have some metallic taste associated with it at certain peak concentrations. This, however, is not a particular health concern. The health effects of concern would be irritation of the mucous membranes (e.g., eyes, throat) as well as coughing and choking. Given that the exposure point concentration levels in Table 5A are less than guideline levels and that the health effects are mild and temporary, you categorize SO_2 as NO THREAT, and you do not evaluate it further in the next step of the risk assessment.

(B) PM_{10}

Though there are no short-term Air-MEGs for PM_{10}, you refer to Appendix C Tables C-4 and C-5 to compare with U.S. general population guidelines. You note that the peak concentration from the sample taken between 1200 and 1300 is in the range for Level 2 of the U.S. General Population Index Criteria for Particulate Matter. Concentrations in this range may cause significant increases in respiratory symptoms, such as coughing, mucous and aggravation of lung disease (e.g., asthma). People with lung disease should avoid outdoors; others should minimize moderate to heavy exertion. The estimated daily average concentration from the three sampling times (268 ? g/m^3) is in the range for Level 1. Again, concentrations in this range may increase respiratory symptoms; people with lung disease should restrict heavy exertion and others should minimize prolonged exertion. Because the daily average concentration of PM_{10} is higher than the general population level, you determine that the PM_{10} exposure may pose a HEALTH THREAT to personnel exposed for 1-14 days. Therefore, you proceed to the next step of the risk assessment.

(C) Mixture of SO_2 and PM_{10}
You note that both SO_2 and PM_{10} exhibit similar health effects, and therefore, that SO_2 may exacerbate the potential effects of PM_{10}. You note that this interaction cannot be quantified, but it should be considered in the overall assessment of the conditions at the base camp.

TABLE 5-B. PRELIMINARY THREAT ANALYSIS FOR AMBIENT AIR

Hazard	Exposure Point Concentration	Standard Guideline		Hazard Classification	Rationale †
		Value	Type		
SO_2	3.1 mg/m^3 (peak concentration)	8 mg/m^3	1-hour Air-MEG Significant Effects Level	No Threat	Exposure point concentration is less than the 1-hour standard guideline for significant health effects
SO_2	3.1 mg/m^3 (assuming 1-hour concentration represents concentration for 8 hours)	5 mg/m^3	8-hour Air-MEG	No Threat	Exposure point concentration is less than the 8-hour standard guideline minimal to non-significant health effects
SO_2	1.3 mg/m^3 (estimated daily average concentration)	2.6 mg/m^3	14-day Air-MEG	No Threat	Exposure point concentration is less than the 1-day standard guideline for minimal to non-significant health effects
PM_{10}	400 ?g/m^3 (peak concentration)	255 – 354 (1) 355 – 424 (2) 425 – 604 (3)	USEPA civilian guidelines ‡	Health Threat	Exposure point concentration is in the range for significant increase in respiratory symptoms
PM_{10}	268 ?g/m^3 (estimated daily average concentration)	255 – 354 (1) 355 – 424 (2) 425 – 604 (3)	USEPA civilian guidelines ‡	Health Threat	Exposure point concentration is in the range for increased respiratory symptoms

†: Additional detail is provided in the text above.
‡: Provided in the TG. The meaning is a modification from the USEPA guidance.
(1) Increased respiratory symptoms. For example, coughing and aggravation of lung disease (e.g., asthma). People with lung disease should restrict heavy exertion; others should minimize prolonged exertion.
(2) Significant increase in respiratory symptoms. For example, coughing, mucous and aggravation of lung disease. People with lung disease should avoid outdoors; others should minimize moderate to heavy exertion.

(3) Serious risk of respiratory symptoms. For example, coughing, mucous, shortness of breath and aggravation of lung disease. All should minimize outdoor exertion.

2. HAZARD ASSESSMENT

Step 2.1. Hazard Severity Evaluation

As stated previously, the types of symptoms caused by exposures to particulate matter include coughing, mucous, shortness of breath and aggravation of lung disease. You determine that these health effects, however, should be limited to mild illness and temporary irritation. You therefore assume that the proportion of personnel responding (i.e., the attack rate) will be few (<10%), which indicates a hazard severity level of NEGLIGIBLE from the Hazard Severity Chart in Table F-2. You note, however, that for asthmatics, the hazard severity may possibly be MARGINAL, but you do remember that Section 4.5 states that the severity of Level 1 is comparable to a minimal effects level and that Levels 2 and 3 are somewhat less severe than significant and severe effects levels.

Step 2.2. Hazard Probability Evaluation

The range of concentrations of PM_{10} is 150 – 400 ?g/m^3 with a peak during the middle of the day. The duration of the concentration peak is not known, so the average daily exposure point concentration presented is highly uncertain, as are the daily ambient air concentrations expected over the course of each two-week deployment to the base camp.

?? Portion of Unit Exposed: Based on the lack of exposure or mission information, you assume that 100% of the field unit will be exposed to PM_{10} every day for the base camp establishment deployment and for the subsequent two-week deployments.

?? Portion of Unit Exposed to Levels Higher than Guidelines: The data collected during the one day of sampling indicate that the field unit may experience PM_{10} exposures that are higher than the U.S. General Population Index Criteria for some portion of the day or as much as most of the day. Given the anticipated fluctuations in concentrations and the possible exacerbating effects from SO_2, you use your professional judgment and assume that most of the unit (>75%) will be exposed to levels higher than the guidelines.

From this information, you use the Hazard Probability Chart from Table F-3 to determine the probability for a two-week deployment. The hazard probability for PM_{10} exposure is categorized as FREQUENT.

Step 2.3. Risk Characterization

Table 5-C summarizes the risk characterization.

Step 2.3.1. Risk Estimate

With the hazard probability and hazard severity, you use the Risk Assessment Matrix in Table F-4 to determine the impact to field units with two-week deployments to the base camp. Based on the hazard rankings the resulting risk estimate is MODERATE. Some unit personnel may experience, coughing, mucous, shortness of breath and aggravation of lung disease (especially asthmatic individuals). This corresponds to an Amber Unit Status (Mission Capable, with minor deficiencies), where the unit is estimated to be at 70 – 84% strength.

Step 2.3.2. Confidence Level

You categorize the confidence level in the risk estimate as LOW for numerous reasons. You only have three samples that were taken on the same day. In addition, to estimate daily exposure point concentrations you made assumptions that introduced uncertainty. In regards to exposure patterns and field unit attributes, you lacked any information; therefore, you took a conservative stance by assuming that the entire field unit will be exposed and most of them at levels higher than the guidelines. You also do not know the respiratory health of the field units' personnel (asthmatics or people with other lung diseases). Also, the guidelines for PM_{10} were determined for the general population rather than for deployed personnel, for durations that are not consistent with the base camp mission and at levels that are not comparable to Air-MEGs. You attempted to account for the possible exacerbating effects of SO_2 on the PM_{10} evaluation by selecting the more conservative probability and severity, but the interaction between the two substances is highly uncertain. You do believe, however, that the predicted health outcome is plausible, given that there is evidence that elevated PM_{10} concentrations have caused respiratory distress in other populations.

Step 2.3.3. Threat Category

Based on the more detailed assessment, you continue to categorize the threat to base camp field units as a HEALTH THREAT.

3. DEVELOP AND COMPARE CONTROLS FOR COA DEVELOPMENT

Step 3.1. Hazard Controls

Because the risk levels are moderate, the need for controls may not be critical, but some attempt should be made to reduce them if not cost or mission-prohibited. The range of options you can present include minimizing exposure by modifying activity patterns or eliminating/minimizing exposure by using personal protective equipment.

The use of protective equipment is not the most desirable option for several reasons. Respiratory protection may offer some control for particulate matter exposure, but it would likely result in residual risks that may be of greater severity — there are several health effects attributed to continuous use of respiratory protection and other personal protective equipment. The possibility of minimizing exposure frequency by modifying activity patterns seems to be the best option. You could recommend that work shifts be no longer than 8 hours and that work be avoided during mid-day. Some other possible control efforts could be to ensure that leaders and soldiers be aware of the hazards and that they know the symptoms of particulate matter exposure. You may also recommend establishment of a contingency plan for excessive exposures and perform pre-deployment screening to ensure that individuals with asthma or other potential respiratory conditions (chronic bronchitis) are not deployed to the base camp.

Step 3.2. Residual Risk

Based on these recommended actions the overall risk to personnel and mission will be minimized to a LOW level.

Step 3.3. Actions to Increase Confidence in Risk Estimate

Initiate environmental exposure surveillance to learn more about durations of concentration peaks, the frequency of the peaks, and the possible sources of SO_2 and PM_{10}.

TABLE 5-C. AMBIENT PARTICULATE MATTER: RISK ASSESSMENT SUMMARY AND RECOMMENDED CONTROLS

CHEMICAL HAZARD	HAZARD RANKING			OPERATIONAL RISK ESTIMATE		PREDICTED HEALTH OUTCOME		CONTROLS & NOTES
	HAZARD TYPE	HAZARD PROBABILITY	HAZARD SEVERITY	RISK LEVEL	CONFIDENCE	DURING DEPLOYMENT	AFTER DEPLOYMENT	
Particulate Matter	Health Threat	Frequent	Negligible	Moderate	Low	Symptoms: respiratory symptoms such as coughing, mucous production and aggravation of lung disease (e.g., asthma) Incidence: >10%	Symptoms: uncertain Incidence:	Modify activity patterns, PPE, increase awareness, develop contingency plan

CS-6 Selecting a Drinking Water Source

MISSION AND ENVIRONMENTAL SETTING

A viable source of drinking water is needed for a two-week operation in the Middle East. Prior to the mission, several potential sources for drinking water were identified and sampled. Using this sampling data you need to decide which drinking water source to use to supply your unit with potable water for the two-week deployment. It's a rather warm arid climate so you need to be able to supply enough water to support consumption rates up to 15 L/day.

1. HAZARD IDENTIFICATION

Step 1.1. METT-TC: Chemicals, Media, and Locations

Three potential sources for drinking water were identified prior to the deployment. There is a primary source and two alternate existing sources all of which are from surface waters. Intelligence reports indicate that the primary source may have been sabotaged with nerve agent. Three water samples were obtained from this drinking water source and sent for lab analysis to confirm this report. Anticipating the potential need for an alternate source, three samples were obtained from each of the two other existing sources and sent for lab analysis – one of which appears to be contaminated through pollution. Your results indicate the presence of nerve agent in the primary source, arsenic in the first alternate source, and benzene, chlorobenzene, and phenol in the second alternate source. All three potential drinking water sources were sampled on the same day during pre-deployment.

Step 1.2. Preliminary Threat Analysis

The sampling data obtained from the primary source are included below.

TABLE 6-A. SAMPLING RESULTS COMPARED TO MILITARY EXPOSURE GUIDELINES FOR THE PRIMARY DRINKING WATER SOURCE

Contaminant	Sample 1	Sample 2	Sample 3	5-day Water-MEG 5 L/day Consumption	5-day Water-MEG 15 L/day Consumption
Nerve Agent – VX	0.02 mg/L	0.03 mg/L	0.02 mg/L	0.015 mg/L	0.005 mg/L

These data confirm your suspicions about your primary source; residual nerve agent VX was detected. A typical initial screening would be to compare the sample results to the long-term Water-MEGs. However, you find that there are no long-term values listed for VX. Therefore, you go directly to the short-term values. There is not a 2-week Water-MEG for VX, so you refer to the 5-day values included

in Table 6-A above. You note that the detected concentrations are above the 5-day Water-MEGs for both consumption rates. You also note these MEGs are in fact TB MED 577 standards and should not be exceeded. As a result, exposures to VX require more evaluation and you classify VX in the primary drinking water source as a MEDICAL THREAT to the mission.

Next you evaluate the first alternate source. The sample results from the first alternate source are provided in Table 6-B.

TABLE 6-B. SAMPLING RESULTS COMPARED TO MILITARY EXPOSURE GUIDELINES FOR ALTERNATE DRINKING WATER SOURCE NO. 1

Contaminant	Sample 1	Sample 2	Sample 3	1-year Water-MEG 5 L/day Consumption	1-year Water-MEG 15 L/day Consumption
Arsenic	0.4 mg/L	0.3 mg/L	0.4 mg/L	0.06 mg/L	0.02 mg/L

You are surprised to find arsenic in your first alternate water source. As a preliminary screening, you compare the sampled concentrations to the 1-year Water-MEGs for arsenic. You note that the values for arsenic are TB MED 577 standards and should not be exceeded. All three of the sample concentrations are greater than the 1-year Water-MEGs indicating that further evaluation is necessary. Since arsenic levels detected are above the TB MED 577standard of 0.1 mg/L it is classified as a HEALTH THREAT and potential MEDICAL THREAT.

Finally, you evaluate the second alternate drinking water source. The sampling results from this source are included below in Table 6-C.

TABLE 6-C. SAMPLING RESULTS FOR ALTERNATE DRINKING WATER SOURCE NO. 2

Contaminant	Sample 1	Sample 2	Sample 3	2-week Water-MEG 5 L/day Consumption	2-week Water-MEG 15 L/day Consumption
Benzene	0.07 mg/L	0.3 mg/L	0.17 mg/L	0.3 mg/L	0.1 mg/L
Chlorobenzene	0.64 mg/L	1.5 mg/L	1.0 mg/L	3 mg/L	1 mg/L
Phenol	2.4 mg/L	3.2 mg/L	1.7 mg/L	8 mg/L	3 mg/L

You had predicted that the second alternate drinking water source had some contamination due to the odor. You check the long-term, 1-year Water-MEGs for your initial screening and find that only benzene

has a value listed (0.042 mg/L and 0.014 mg/L for 5L/day and 15 L/day consumption rates, respectively). The detected benzene concentrations are well above this level, so you check the short-term values for benzene along with the other detected contaminants. Since the deployment duration is 2-weeks you use the 2-week Water-MEGs which are included in Table 6-C above. You compare the sampled concentrations to the 2-week Water-MEGs for the 15 L/day consumption rate. There are some samples for each contaminant that are greater than the Water-MEG. Therefore, this source is considered HEALTH THREAT and requires further evaluation as well.

2. HAZARD ASSESSMENT

Step 2.1. Hazard Severity Evaluation

In this step you need to consider the potential health effects associated with the various contaminants detected in the different water supplies and assign a hazard severity ranking to each.

(A) Primary Source

The TB MED 577 provides information on the health effects from exposure to organophosphorus nerve agents and is summarized below in Table 6-D. Performance-degrading health effects can include abdominal cramps, vomiting, diarrhea, and headaches. The concentration of nerve agents at which death might occur from repeated ingestion of drinking water over the course of several days has not been determined but is estimated to be 0.11 mg/L.

TABLE 6-D. ESTIMATED HEALTH EFFECTS FROM INGESTION OF ORGANOPHOSPHORUS NERVE AGENTS IN DRINKING WATER

Consumption Rate	Safe Water Concentration* (mg/L)	Increasing Risk of Performance Degrading Health Effects and Mortality (mg/L)	Possibility of Respiratory Distress Requiring Resuscitation (mg/L)**
5 L/day	0 - 0.012	0.012+	0.03
15 L/day	0 - 0.004	0.004+	0.01

*Based on GD since it appears to be the most toxic nerve agent where a total dose from field water is ingested in several drinks over the course of the day for an exposure period lasting up to 7 days.
**Based on single intravenous dose of VX in human volunteers.

All samples from the primary drinking water source had concentrations that are greater than the 5-day Water-MEGs for VX and the estimated concentration for severe health effects. On the basis of the information gathered regarding exposure to VX in drinking water, you estimate the severity level associated with the primary source as CATASTROPHIC using the Chemical Hazard Severity Ranking Chart in Table F-3. You determined this by comparing the sample concentrations to the estimated health effects in Table 6-D. For exposures to concentrations at the sample levels you would expect many personnel to experience incapacitation or death during the mission. This estimation reflects your particular concern regarding the small difference between a "safe" level and a "lethal" level. This small difference (referred to as a steep dose-response curve) means that a minor fluctuation in concentration can have catastrophic effects. In addition, since the concentrations are being compared to TB MED 577 standards that do not have built in safety factors, it is likely that a high percentage of the unit will experience some degree of symptoms if exposed above the standard.

(B) Alternate Source No. 1
Since all three of the arsenic concentrations were greater than the 1-year Water-MEGs, you check the short-term MEGs (a TB MED standard). Only a 5-day value for arsenic is listed: 0.3 mg/L (5 L/day consumption) and 0.1 mg/L (15 L/day consumption).

The sampled concentrations are also greater than the 5-day Water MEGs for the 15 L/day consumption rate. The TB MED provides information on the health effects from arsenic exposure in drinking water and is summarized in Table 6-E. Symptoms of acute arsenic toxicity may include edema, nausea, vomiting, headache, and abdominal pain. Characteristic symptoms of chronic arsenic toxicity include skin effects, gastrointestinal problems, peripheral vascular disease, and neurological changes.

TABLE 6-E. HEALTH EFFECTS FROM INGESTION OF ARSENIC IN DRINKING WATER

Consumption Rate	Exposure Duration	Safe Water Concentration (mg/L)	Increasing Risk of Developing Symptoms of Toxicity (mg/L)	Increasing Risk of Lethality (mg/L)
5 L/day	$\leq$ 7 days	0 – 0.3	0.3 – 14	14+
15 L/day	$\leq$ 7 days	0 – 0.1	0.1 – 4.7	4.7+
5 L/day	$\leq$ 1 year	0 – 0.06	0.06+	--
15 L/day	$\leq$ 1 year	0 – 0.02	0.02+	--

The information available regarding arsenic exposure in drinking water indicates that the risk of developing symptoms of acute toxicity increases as the concentration increases above 0.1 mg/L. The risk of severe toxic effects and fatalities increases as concentrations rise above 4.7 mg/L. You also recall that the comparison levels for arsenic are TB MED standards that do not have built in safety factors. Since the detected concentrations are all three to four times above the level that can begin to produce an acute effect, it is likely that most of the unit will begin to experience symptoms. On the basis of this information combined with the Chemical Hazard Severity Ranking Chart in Table F-2, you estimate the severity level associated with this source as CRITICAL as many personnel may experience symptoms that impair functional abilities during the mission.

(C) Alternate Source No. 2
You go to Appendix D to obtain additional information that is summarized below in Table 6-F. The absence of a carcinogen statement for chlorobenzene and phenol implies that they are not carcinogens. In addition, the notes section for phenol indicates that phenol can react with the water supply disinfectant hypochloride to produce objectionable tastes and odors. The odor you noticed is consistent with the findings. (Note that the odor thresholds are surpassed for both chlorobenzene and phenol.)

You are concerned that all contaminants are above the short-term Water-MEG, but you realize that the information you have does not clearly indicate how severe the health effects from exposure to these concentrations might be. The Water-MEGs are exceeded for one of the three samples for chlorobenzene and phenol and for two of the three samples for benzene if the consumption rate is 15 L/day. If you average the three water samples, only the averaged benzene concentration is greater than the Water-MEG for the 15 L/day consumption rate. You do note that the level for benzene is considerably below lethal levels and that the level for phenol is considerably below that which will cause dangerous effects. You also note that two of these contaminants have potential effects on the CNS and two can cause liver and kidney damage so you consider potential additive effects. The sampled concentrations for all three

substances are less than or only slightly over the guidelines. Therefore, you anticipate that few personnel will exhibit symptoms from exposure to these chemicals and that the symptoms can be considered mild illness or temporary irritation. Using the Chemical Hazard Severity Ranking Chart Table F-2, you rank the severity of exposures to contaminants in this water source as NEGLIGIBLE.

TABLE 6-F. ADDITIONAL HEALTH INFORMATION FOR CONTAMINANTS IN ALTERNATE DRINKING WATER SOURCE NO. 2

Contaminant	Potential Symptoms	Target Organ	Odor and Taste Thresholds	Human Carcinogen
Benzene	Vomiting, loss of coordination, light-headedness, headache, and anemia are a few.	Eyes, skin, respiratory system, blood, CNS, bone marrow, immune system	Odor: 2.0 mg/L Taste: 0.5 – 4.5mg/L	Yes
Chlorobenzene	Drowsiness, dizziness, light-headedness, and muscle spasms are a few	CNS, liver, kidneys	Odor: 0.05 mg/L Taste: 0.01 – 0.02 mg/L	No
Phenol	Corrosion of the mouth, throat, and stomach, nausea, and vomiting are a few.	Liver, kidneys, cardiovascular system	Odor: 0.3 mg/L	No

Step 2.2. Hazard Probability Evaluation

Though only three samples were collected from each water source, it is assumed that the data are representative of each of the water sources. Since the water supply would be the sole source of potable water for the camp, all personnel would be exposed to the contaminants present in the water on a daily basis for the duration of the mission. For the primary and first alternate sources, since the levels of contaminants detected are significantly above the TB MED 577 standards for all samples, it is assumed that a high percentage of the unit will be exposed to levels above the standard. Therefore, based on the Chemical Hazard Probability Ranking Chart in Table F-3, the hazard probability should be considered FREQUENT. For the second alternate source, the concentrations are close to acceptable levels and are not above the appropriate guidelines in one of the three samples. Therefore, the hazard probability is somewhat lower than the other two sources since it is assumed that two-thirds of the time personnel will be exposed to levels greater than the Water-MEGs. The probability for this source is considered LIKELY based on the Chemical Hazard Probability Ranking Chart.

Step 2.3. Risk Characterization

Table 6-G presents the risk characterization summary.

2.3.1. Risk Estimate

After estimating the hazard probability and hazard severity in the previous steps, you use the Risk Assessment Matrix in Table F-4 to determine the impact to the unit during a two-week operation at the camp. Both the primary and first alternate drinking water source present an EXTREMELY HIGH operational risk based on their hazard rankings. The second alternate source presents only a LOW level of operational risk to the unit.

2.3.2. Confidence Level

Your confidence in the operational risk estimates for each of the drinking water sources is considered MEDIUM based on the information available for the assessment. You know sufficient information about the expected exposures for the unit (duration, water consumption rate, high activity level). There is sampling data available for each drinking water source that was analyzed in a laboratory (in contrast to estimates from portable water kits and test strips). Water-MEGs are available for all contaminants detected and for the duration of interest (2-week comparison MEGs) in addition to information on potential health effects. There is some uncertainty in the potential fluctuations of contaminant concentrations in the water due to not knowing the contaminant sources. This is especially true for the primary source since VX has a half-life of 50 hours in water. If the primary source was not intentionally contaminated again, concentrations of VX should continually decrease but without further intelligence and sampling information to confirm this, it was assumed the unit would be exposed to the sampled concentrations.

2.3.3. Threat Category

The last step in the risk characterization is to place each of the hazards into health threat categories. You reassess your categories from the Preliminary Threat Analysis based on the complete hazard assessment. The hazards presented by the primary and first alternate drinking water source are classified as MEDICAL THREATS because they have the potential to render the unit mission ineffective. The hazards presented by the second alternate source are considered HEALTH THREATS since they are not expected to have immediate medical impacts on the overall mission effectiveness although they may cause adverse health effects in some individuals.

3. DEVELOP AND COMPARE CONTROLS FOR COA DEVELOPMENT

Step 3.1. Hazard Controls

In conclusion, you determine that bottled water is the preferred choice, but given no immediate access to a bottled supply, interim use of the second alternate source would be the next option since this source presents only a low operational risk level.

Step 3.2. Residual Risk

If bottled water was used as a drinking water source you could ensure that the overall risk level remained low. However, you could maintain a low operational risk level while using the second alternate water source if you could ensure that concentration levels are maintained or decreased.

Step 3.3. Actions to Increase Confidence in Risk Estimate

The continued monitoring of the second alternate drinking water source recommended above will also serve to increase your confidence in the risk assessment. With additional data, you would have a better understanding of the contaminant levels in the water source, which would lead to a better estimate of operational risk.

TABLE 6-G. DRINKING WATER SOURCES: RISK ASSESSMENT SUMMARY AND RECOMMENDED CONTROLS

CHEMICAL HAZARD	HAZARD RANKING			OPERATIONAL RISK ESTIMATE		PREDICTED HEALTH OUTCOME		CONTROLS & NOTES
	HAZARD TYPE	HAZARD PROBABILITY	HAZARD SEVERITY	RISK LEVEL	CONFIDENCE	DURING DEPLOYMENT	AFTER DEPLOYMENT	
VX in Primary Source	Medical Threat	Frequent	Catastrophic	Extremely High	Medium	Symptoms: abdominal cramps, vomiting, diarrhea, headaches, respiratory distress are a few Incidence: >25%	Symptoms: uncertain Incidence:	Alternate source of drinking water such as bottled water or interim use of Alternate Source No. 2
Arsenic in Alternate Source No. 1	Medical Threat	Frequent	Critical	Extremely High	Medium	Symptoms: edema, nausea, vomiting, headache, abdominal pain Incidence: >25%	Symptoms: skin effects, gastrointestinal problems, peripheral vascular disease, neurological changes Incidence:	Alternate source of drinking water such as bottled water or interim use of Alternate Source No. 2
Benzene, Chlorobenzene and Phenol in Alternate Source No. 2	Health Threat	Likely	Negligible	Low	Medium	Symptoms: vomiting, headache, dizziness, muscle spasm are a few Incidence: 0 – 10%	Symptoms: cancer, immune system depression, liver or kidney damage for benzene Incidence:	Alternate source of drinking water such as bottled water or continuous monitoring

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CS-7 Selection of Base Camp Sites

MISSION AND ENVIRONMENTAL SETTING

You are assisting with the planning for a peacekeeping mission in Central America. Two proposed base camps have been chosen. Each site could be used as a logistics base. You have been tasked to assess the environmental health-risk level for each COA.

While many other factors will come to play in the final selection process, your commander is concerned about the potential health impacts associated with what will be a long–term (up to one year) stay for most the personnel deployed to the area. The operation will commence 90 days from today. You were allowed time to conduct a very brief, initial reconnaissance of each site. Your onsite reconnaissance results are presented below.

1. HAZARD IDENTIFICATION

Step 1.1. METT-C: Chemicals, Media, and Locations

(A) COA 1. Base Camp Raptor

Base Camp (BC) Raptor is located adjacent to a river. This is muddy, and is the probable water supply. The BC is to be used only as a bulk refueling point and DS maintenance support asset. Personnel assigned to this site will primarily include (other activities will occur at other locations):

- Security personnel (A mechanized infantry line company), who will be manning a minimal perimeter in fixed positions constructed by army engineers 2 weeks into the operation.
- DS Maintenance Personnel who will be performing maintenance in a common (unimproved) motor pool.
- Logistics Personnel who will manage and distribute all classes of supply from a tent city to be constructed by Air Force Engineers during the first 7 days of the operation.

The tent city and maintenance areas are separated by an elevated road and are about 50 meters apart. There will not be a shower point at this site so solders will have to be rotated out for showers. The current plan is to have a daily shower run where 1/3 of the base camp gets a shower (i.e., a shower every three days).

At the south end of the site, you find the remains of a concrete pad. Local civilians tell you that there used to be an above ground fuel tank at this location. The tank was hit during a recent air attack. He tells you that after the fuel tank exploded, a fire burned for about six hours. This fire spread out 60 meters in all directions. You notice a faint stained area around the pad that appears to be contaminated, and a very weak sweet smell. You decide to take air, water, and soil samples to evaluate various exposures from the site. Sampling results are summarized in Table 7-A.

TABLE 7-A. BASE CAMP RAPTOR SAMPLE RESULTS

Medium	Chemical	DF	Mean	Standard Deviation	Maximum	TG 230 Long-Term MEG
Soil (mg/kg)	Lead	8 / 8	184	103	426	2200
	Lindane	* 4 / 8	301	506	785	560
	Benzo[a]anthracene	† 3 / 8	0.78	1.3	2.14	2500
	Ethyl Benzene	**† 3 / 8**	**600**	**635**	**1066**	**230**
	Toluene	† 3 / 8	480	301	887	520
	Xylene	† 3 / 8	88	40	190	210
	Chrysene	† 3 / 8	2975	6000	4470	3100
Water (mg/L)	Lindane	1 / 1	—	—	0.03	0.2 – 0.6
	Mercury	**1 / 1**	**—**	**—**	**0.002**	**0.0003 – 0.0007**
Air ‡ (?g/m^3)	**Benzene**	**1 / 1**	**—**	**—**	**160**	**39**
	Carbon Tetrachloride	1 / 1	—	—	33	320
	Dichloroethane	1 / 1	—	—	13	180

DF: Detection frequency
* These four detects are from randomly scattered locations, i.e., that are not grouped.
† These three detects were taken from the spill area.
‡ Air samples were averaged over the 0800 – 1000 time period (2 hours).

(B) COA 2. BC Wolverine

In this COA, BC Wolverine activities would include all the activities proposed for BC Raptor and much more of the operational load including housing many of the war fighters, and their motor pools.

- ?? Administrative personnel for the larger units.
- ?? DS Maintenance Personnel who will be performing maintenance in a common (unimproved) motor pool. These personnel will rotate out every third day and perform work at a remote site that has a dedicated hardstand for maintenance.
- ?? Logistics Personnel who will manage and distribute all classes of supply from fixed facilities.
- ?? Security personnel (a light infantry battalion) who will man a minimal perimeter in permanent positions constructed by army engineers 2 weeks into the operation.

BC Wolverine is a site 10 miles north of BC Raptor – inland from the river in a shallow valley. You can see what appears to be an industrialized area further up the valley.

The site was selected for logistical reasons to include the existing abandoned warehouses present. Access roads are nearby, and you have been told that local bottled water from the nearby city would be provided. There are no surface water bodies present. You decide to take air and soil samples to evaluate various exposures from the site. Sampling results are summarized in Table 7-B.

TABLE 7-B. BASE CAMP WOLVERINE SAMPLE RESULTS

Medium	Chemical	DF	Mean	Standard Deviation	Maximum	TG 230 Long-Term Guideline
Soil (mg/kg)	Fluoranthene	3 / 11	133	88	370	42000
	Lead	11 / 11	688	1100	4200	2200
Water (mg/L)	Bottled water data is unavailable					
Air * (mg/m^3)	**Mercury**	**1 / 1**	**—**	**—**	**3.2**	**0.21**
	Carbon Tetrachloride	**1 / 1**	**—**	**—**	**0.34**	**0.32**

DF: Detection frequency
* Air samples were averaged over the 1500 – 1600 time period (1 hour).

Step 1.2. Preliminary Threat Analysis

Preliminary (health or medical) threats were identified by screening media concentrations using long term MEGs. Concentrations that were above the MEGs were initially considered health threats and were analyzed further. Those chemicals retained for further analysis are summarized in Table 7-C.

TABLE 7-C. POTENTIAL HEALTH THREATS

Base Camp	Medium	Chemical	DF	Mean	Standard Deviation	Max	1-year MEG
Raptor	Soil (mg/kg)	Ethyl Benzene	† 3 / 8	600	635	1066	230
	Water (mg/L)	Mercury	1/1	—	—	0.002	0.0003#
	Air ‡ (ug/m^3)	Benzene	1/1	—	—	160	39
Wolverine	Air * (ug/m^3)	Mercury	1/1	—	—	3.2	0.21
		Carbon Tetrachloride	1/1	—	—	0.34	0.32

DF: Detection frequency
* Air samples were averaged over 1 hour. (1500 – 1600).
† These three detects were taken from the spill area.
‡ Air samples were averaged over 2 hours. (0800 – 1000)
# Retain most conservative of the possible values (For 15 L/ Day)

(A) BC Raptor
Based on the sampling results and screening with MEGs the HEALTH THREATS for BC Raptor are ethyl benzene in soil, mercury in water and benzene in air.

(B) BC Wolverine
Based on the sampling results and screening with MEGs the HEALTH THREATS for BC Wolverine are mercury and carbon tetrachloride in air.

2. HAZARD ASSESSMENT

Step 2.1. Hazard Severity Evaluation

(A) BC Raptor

Air: The effects associated with excessive benzene exposure in air are listed in TG 230 Appendix C. Initial symptoms irritation of eyes, nose and throat and potentially followed by other respiratory symptoms. The effects you expect to see are mild injury or temporary irritation amongst a small portion (e.g. <10%) of the population. According to the Hazard Severity Ranking Chart in Table F-2, you chose a hazard severity of NEGLIGIBLE for airborne chemical hazards.

Water: The effects associated with excessive exposure to mercury in water are listed in TG 230 in Appendix D. Initial symptoms include, tremors, fatigue and other CNS effects. The effects you expect to see are mild injury or temporary irritation amongst a small portion of the exposed personnel. As a result, you chose a hazard severity of NEGLIGIBLE for chemical hazards in drinking water per suggested TG230 Severity Ranking Chart).

Soil: The effects associated with excessive exposure to ethylbenzene are listed in TG 230 in Appendix E. Initial symptoms include, headache, nausea, dizziness and other CNS effects. Based on the concentration found, the volatility only a small portion (e.g. <10%) of personnel would be expected to exhibit symptoms. The effects you expect to see are mild injury or temporary irritation. As a result, you chose a hazard severity of NEGLIGIBLE for chemical hazards from soil (per the Hazard Severity Ranking Chart in Table F-2).

(B) BC Wolverine

Soil: No health threats were identified in the soil at this location.

Water: The water supply for this site is going to be obtained as bottled water from a certified source –so no health threat is associated with this pathway.

Air: Mercury and carbon tetrachloride in air were identified as a potential health threat.

1) The effects associated with excessive exposure to mercury in air are listed in TG 230 Appendix C. Initial symptoms (expected initially amongst a small portion of personnel) include irritation to eyes and skin; chest pain, dyspnea and other respiratory effects. You categorize the effects you expect to see as mild injury or temporary irritation. Per the suggested Hazard Severity Ranking Chart, you chose a hazard severity of NEGLIGIBLE for this airborne chemical hazard.

2) The effects associated with excessive exposure to carbon tetrachloride are listed in TG 230, Table Appendix C. Initial symptoms include irritation to eyes and skin; nausea and vomiting and other CNS effects. But based on the concentration found and the volatile nature of this chemical, you expect to see mild injury or temporary irritation amongst a small portion of the exposed group. As a result, you chose a Hazard severity of NEGLIGIBLE for this airborne chemical hazard.

Step 2.2. Hazard Probability Evaluation

(A) BC Raptor

Soil: Only ethyl benzene was identified as a potential health threat in soil. It was detected only in the locations where residual material from the fire remained. You notice that this is the area where all maintenance work will be performed. You decide that in order establish a risk level; you will select the most exposed soldier. In this case, it is the DS maintenance personnel because you expect them to have intimate, prolonged contact with the soil for the entire duration (working in an unimproved motor pool and they get a shower every three days).

You and the surgeon identify that the DS maintenance section is mission critical for the mission at this location, and that most if not all personnel will be exposed. However, you estimate that only 20 – 50 percent (Hazard Probability Ranking Chart in Table F-3) of the unit will contact soil at levels above the TG 230 guideline of 230 mg/kg. In addition, ethyl benzene is a volatile chemical, and should not be present for the entire year at this concentration.

As a result, the hazard probability for chemicals in soil at BC Raptor is chosen to be OCCASIONAL. You suspect that this is an overestimate due to the volatility, but decide to retain this estimate in order to be conservative.

Water: Mercury in water was identified as a potential health threat. Because this is the sole water source, all soldiers will drink from this water every day. As a result, the hazard probability was chosen to be FREQUENT. Though you note that this is a single sample, and may not adequately characterize the water supply.

Air: Benzene in air was identified as a potential health threat. Because this is an ambient measurement, the hazard probability was chosen to be FREQUENT. Though you note that this is a single sample, and may not adequately characterize the ambient conditions.

(B) BC Wolverine

Soil: No health threats were identified in the soil at this location

Water: The water supply was not tested.

Air: Mercury and carbon tetrachloride in air was identified as a potential health threat. Because these were ambient measurements, the hazard probability was chosen to be FREQUENT. Of course, these were taken as a single sample, and may not adequately characterize the ambient conditions.

Step 2.3. Risk Characterization

Tables 7-D and 7-E present the risk characterization summaries for each BC.

2.3.1. Risk Estimate

Based on the assessment of severity and probability of chemical hazards in various media at each site, you consider the FM 100-14 Operational Risk Management matrix in Table F-4 and conclude that the overall risks at both sites are similar –both are ranked MODERATE.

2.3.2. Confidence Level

(A) BC Raptor

The overall Moderate risk level associated with BC Raptor is driven by the benzene levels in the air and water in that area. However, the confidence in this risk estimate is LOW. This is primarily due to the lack of representative concentration data. Both the benzene and mercury concentrations were evaluated using single measurements, which may not be representative of the ambient concentrations of these chemicals. Exposure data is limited as well. The risk assessment is based on an arbitrary decision to use maintenance personnel as the most exposed person. This assumption will necessarily make the risk level an over conservative estimate of the risk to the rest of the personnel at this site.

(B) BC Wolverine

The risk level associated with BC Wolverine is also considered Moderate due to the mercury and carbon tetrachloride concentrations in air. This risk level assumes that the water selected for use at this site will not be a health threat for this location. The confidence in the overall risk level is considered LOW, however, mainly because of the lack of representative data. Both airborne chemical concentrations were evaluated using single measurements take over the space of 1 hour, which may not be representative of the ambient concentrations of these chemicals.

2.3.3. Threat Category

Based on these assessments, you believe that the environmental conditions at both sites may be HEALTH THREATS but should not be considered medical threats.

3. DEVELOP AND COMPARE CONTROLS FOR COA DEVELOPMENT

You present the risk levels above to the J3. Based on the BC risk assessment, you have estimated that the chemical hazards present at the two sites present a similar degree of risk (Moderate), and that you can only estimate this with a Low degree of confidence. However, you give slight preference to the use of BC Wolverine due to two factors. First, there is only one exposure pathway (inhalation) of concern at this site – soil samples suggest that soil contamination is not a health threat; and a bottled water supply negates concerns about this source. Second, the two contaminants present in the air do exceed MEGs, however, carbon tetrachloride (a B2 carcinogen) just barely exceeds the long-term Air-MEG and is substantially below its associated short-term exposure MEGs. Mercury more significantly exceeds the long-term MEG – but you notice there are no short-term MEGs for this compound, suggesting perhaps it is not a critical acute hazard. Though only one chemical was detected in the air at BC Raptor, you have hazards of concern in both water and soil as well. Even though soil and water pathways could be somewhat controlled, the benzene from the air is of particular concern. It is a Class A (known human) carcinogen and you note that not only does the sample level exceed the 1-year MEG, it is right at the 14-day MEG.

Step 3.1. Hazard Controls

Selection of the BC location in this case may be driven by other factors (such as logistical benefits, etc) since chemical hazards at both sites are of similar severity and probability. If BC Raptor is selected,

specific controls can be instituted to prevent/minimize exposures to chemicals in soil (educate personnel on minimizing contact (using clothing/gloves as barriers) and cleaning more frequently) and drinking water (such as obtain bottled water source). The airborne hazards that are present at either site are going to be difficult to minimize, so exposures will need to be documented. Continued monitoring of the ambient air situation will provide further information that could be used to control the risk to personnel at either site. In addition, source investigation may identify where these chemicals are coming from, and if concentrations remain at these levels or increase, active measures to control it could be implemented depending on the situation.

Step 3.2. Residual Risk

Even if soil and water hazards are eliminated from BC Raptor, the airborne hazard will still present a Moderate Risk. Likewise, there are no viable controls to reduce the Moderate Risk present at BC Wolverine.

Step 3.3. Actions to Increase Confidence in Risk Estimate

The major uncertainty in the risk estimate at both locations is the lack of data. Further actions should include more representative sampling in order to characterize the temporal aspects of the exposures. In addition, some investigation of the sources of the air pollution should be performed. The results of these investigations may be used to manage or eliminate the exposures (stop mercury emissions around wolverine) if the political/strategic situation allows.

TABLE 7-D. BASE CAMP RAPTOR RISK ASSESSMENT SUMMARY AND RECOMMENDED CONTROLS

CHEMICAL HAZARD	HAZARD RANKING			OPERATIONAL RISK ESTIMATE		PREDICTED HEALTH OUTCOME		CONTROLS & NOTES
	HAZARD TYPE	HAZARD PROBABILITY	HAZARD SEVERITY	RISK LEVEL	CONFIDENCE	DURING DEPLOYMENT	AFTER DEPLOYMENT	
Ethyl Benzene in Soil	Health Threat	Occasional	Negligible	Low	Medium	Symptoms: lightheadedness, headaches; dizziness; fatigue Incidence: <10%	Symptoms: uncertain Incidence:	Inform personnel to minimize contact/use of clothing/gloves; Increase allotted shower frequency
Mercury in Water	Health Threat	Frequent	Negligible	Moderate	Low	Symptoms: fatigue, tremors, loss of motor skills/visual acuity/higher mental function; weakness memory loss Incidence: <10%	Symptoms: Liver and kidney damage; memory loss Incidence: <10%	Alternate source of drinking water such as bottled water
Benzene in Air	Health Threat	Frequent	Negligible	Moderate	Low	Symptoms: Irritation of eyes, skin, nose, respiratory system; giddiness; headache, nausea, staggered gait; fatigue, anorexia, lassitude (weakness, exhaustion); dermatitis; Incidence: <10%	Symptoms: bone marrow depression, leukemia; cancer. Incidence: <10%	Continuous monitoring/ alternate site; exposures difficult to minimize – known (A) carcinogen; document exposures in personal records
Overall Threat	**Health Threat**	**Frequent**	**Negligible**	**Moderate**	**Low**			**Consider alt. site**

TABLE 7-E: BASE CAMP WOLVERINE RISK ASSESSMENT SUMMARY AND RECOMMENDED CONTROLS

CHEMICAL HAZARD	HAZARD RANKING			OPERATIONAL RISK ESTIMATE		PREDICTED HEALTH OUTCOME		CONTROLS & NOTES
	HAZARD TYPE	HAZARD PROBABILITY	HAZARD SEVERITY	RISK LEVEL	CONFIDENCE	DURING DEPLOYMENT	AFTER DEPLOYMENT	
Mercury and Carbon Tetrachloride in Air	Health Threat	Frequent	Negligible	Moderate	Low	Symptoms: Irritating to eyes, skin; cough, chest pain, dyspnea, bronchitis, pneumonitis; tremor, insomnia, irritability, indecision, drowsiness, dizziness headache, fatigue, weakness; stomatitis, salivation, GI distress, anorexia Incidence: <10%	Symptoms: liver, kidney injury; cancer (carbon tet) Incidence: <10%	Continuous monitoring/alternate site; exposures difficult to minimize – known carcinogen; document exposures in personal records
Overall Site Risk	**Health Threat**	**Frequent**	**Negligible**	**Moderate**	**Low**			**Preferred site**

APPENDIX G

DRINKING WATER PURIFICATION

The Performance of the Reverse Osmosis Water Purification Unit (ROWPU) with Respect to Removal of Soluble Contaminants from Source Waters

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WATER QUALITY INFORMATION PAPER NO. IP-31-014
WATER PURIFICATION BY REVERSE OSMOSIS

1. PURPOSE. This information paper provides guidance on the performance of the reverse osmosis water purification unit (ROWPU) with respect to removal of soluble contaminants from source waters. It is intended for the use of all preventive medicine and water point personnel, whether or not they have received formal instruction in membrane technology.

2. DISCUSSION.

a. Principles.

(1) Osmosis, for our purpose, is the process whereby water passes through a ?semipermeable? membrane, i.e., a membrane that obstructs the passage of salt or other material dissolved in the water. The direction of water passage is from the dilute solution side of the membrane to the concentrated side. For example, if a living cell is emersed in distilled water, the cell swells - sometimes to the bursting point - as water flows in through the cell membrane. If, on the other hand, the same cell is emersed in a saturated salt solution, water flows out and the cell is dehydrated, which is how road salt kills vegetation.

(2) Applying pressure to the concentrated solution side of a membrane reverses this osmotic process. This process allows us to construct a device to extract pure - or nearly pure - water from solutions of salt and other dissolved materials in a manner analogous to distillation, except that pressure provides the driving force rather than temperature. The ROWPU is such a device.

b. Removal of Simple Salts.

(1) It is important to understand that the original 600 gph ROWPU was designed to produce potable water from seawater or brackish water, i.e., to remove sea salts, principally sodium chloride or common salt. Other significant seawater constituents include salts of magnesium, calcium and potassium, as well as salts of bromine, sulfur (in the form of sulfate) and carbon (in the form of carbonate and bicarbonate). The product water from the ROWPU has 98- 99 percent of the sodium chloride removed (?rejected?) and at least that much of the other sea salts. Ordinary seawater contains about 3.5 percent (35,000 ppm) sea salts, so the product water should contain 350-700 ppm dissolved salts. This is more salt than in most municipal drinking water, but it is still well within the Army field water standard (1,000 mg/L). Note that if the seawater contains more than 3.5 percent salts, as is the case in the Persian Gulf, the ROWPU still removes just 98-99 percent. Thus, if the seawater contains 6 percent (60,000 ppm) salts, the product water will contain 600-1,200 ppm and may taste very slightly brackish. If, on the other hand, the ROWPU is used to purify fresh water, the product water may contain almost no salts and may taste ?flat.

(2) The membranes in the ROWPU are manufactured to remove sea salts. Any other chemical removal is a bonus, but such removal must be determined experimentally for the particular membrane, for each chemical, and for the conditions (temperature, pH, pressure) under which the equipment will be used. Some typical rejection data are presented in Table 1 for membranes similar to those used in the ROWPU. However, many new membranes, tailored for specific purposes, are being marketed. Some of these membranes may give significantly improved salt rejection and may provide greatly altered selectivity.

TABLE 1. REJECTION OF SALTS BY A TYPICAL RO MEMBRANE*

Salt	Rejection, percent
Sodium chloride	98
Magnesium chloride	98
Calcium chloride	99
Magnesium sulfate	99
Sodium bicarbonate	98
Sodium nitrate	93
Sodium fluoride**	98

* Filmtec[1], spiral wound, thin film composite polyamide. Data are provided by the manufacturer for pure solutions of each salt; they are not applicable to mixtures of salts.
**Fluoride rejection is pH dependent: about 75% at pH 5, 50% at pH 4, 30% at pH 3.5 and 0 % at pH <3.

c. Industrial Inorganic Chemicals.

(1) Most inorganic salts, including industrial chemicals, are removed from water by the ROWPU as well as sodium chloride. However, some inorganic salts are poorly removed (Table 2). Product water from a river contaminated with plating wastes will probably have 98-99 percent of nickel, copper and zinc removed and 96-98 percent of the cadmium, but perhaps only 90 percent or less of the chromium and cyanide. This may not seem like much of a difference, but note that a process which removes 90 percent of a pollutant leaves 10 times as much of the . pollutant in the product water as one that removes 99 percent. Removal efficiency is poor for mercury (33-78 percent) and arsenic (69-99 percent, depending on the chemical form). Removal efficiency is good for iron and manganese, but these metals may cause excessive fouling of the membranes.

[1] Filmtec is a registered trademark of FilmTec Corporation, Minneapolis, MN.

TABLE 2. REJECTION OF HEAVY METAL SALTS BY TYPICAL RO MEMBRANES

Salt	Rejection, percent
Nickel sulfate	99
Copper sulfate	99
Arsenic (+5) salts	99
Arsenic (+3) salts	69 and lower
Cadmium salts	99
Lead salts	97
Mercury salts	37-78
Chromium (+6) salts	97
Chromium (+3) salts	96

(2) Many of the common heavy metals found in polluted waters (lead, mercury, cadmium, arsenic, and chromium in particular) are highly toxic, and while the ROWPU may remove them well enough to meet health standards, it is still important to select the best raw water source available. This places increasing importance on the role of preventive medicine personnel in the process of water point site selection.

d. Organic Chemicals.

(1) Removal of organic materials may depend on size (i.e., molecular weight), structure and substitution (Table 3). Natural organic materials in water (lignans, tannins, fulvic substances) are essentially all removed, as are carbohydrates, proteins, and amino acids. Rejection of contaminants from industrial sources is highly variable. Removal efficiency is poor for low molecular weight alcohols such as methyl, ethyl, propyl and isopropyl alcohol, as well as for most low molecular weight solvents, including chlorinated solvents. In general, initial removal improves with increase in molecular weight, but this may be deceiving. Many organic contaminants that show good short-term removal in bench tests may ?leak? through the membrane in days or even hours. For example, removal of lindane may fall from an initial 97 percent to 85 percent after 24 hours. Weak organic acids of low molecular weight (acetic acid and its simple derivatives, propionic acid, butyric acid, phenol) are poorly removed.

TABLE 3. REJECTION OF SOME ORGANIC CHEMICALS BY TYPICAL RO MEMBRANES

Chemical	Rejection, percent
Aldehydes and Alcohols	
Formaldehyde	35
Methanol	25
Ethanol	70
Isopropanol	90
Sucrose (cane sugar)	99
Acids	
Acetic acid	60-90
Fluoroacetic acid*	98-99
Phenol	56-87
Benzoic acid	87-92
Solvents	
Trihalomethanes	50-80
Chloroethylenes	15-90
BTEX	15-50
Chlorobenzene	40-50
Herbicides	
Atrazine	96
Alachlor	98
Linuron	98

* Rodenticide; extremely toxic to humans

(2) Most organics will not cause acute health problems at the concentrations found even in polluted source water, although they may impart a taste so unpleasant that consumers will risk dehydration rather than drink it. However, some may present the risk of long-term health problems such as cancer. Because of the uncertainty in efficiency of rejection of industrial organics, it is again important to select the least contaminated source water for treatment. Surface waters immediately downstream from municipal or industrial outfalls should be avoided, in particular the outfall from a petrochemical complex

e. NBC Agents. Removing NBC agents from water by RO has received only limited investigation (Table 4). A single study indicates that the biotoxins, such as ricin, are reduced below detection limits by membranes similar to those in the ROWPU. Other studies indicate better than 99 percent removal for chemical agents and 95 percent or better removal for certain radioactive chemicals (nuclear agents). However, it is also known that radioactive materials eventually damage RO membranes. Furthermore, it may be assumed that membranes exposed to a constant challenge will eventually pass larger concentrations of chemical agents (but not most biotoxins).

TABLE 4. REJECTION OF NBC AGENTS BY REVERSE OSMOSIS

Agent	Rejection, percent
T-2	100
Microcystin	100
Ricin	100
Saxitoxin	100
GB	>99
VX	>99
BZ	>99
Hydrogen cyanide	<25*
^{131}I	>95
^{85}Sr	>99
^{134}Cs	>98

*pH $\leq$ 8.5

f. Parasites, Bacteria and Viruses. Reverse osmosis membranes have not, for the most part, been specifically tested for removal of bacteria, viruses, and parasites, such as *Giardia* or *Cryptosporidium* cysts. Based on size exclusion, it may safely be assumed that an undamaged membrane will remove virtually 100 percent of all microbiological organisms (although recent studies have indicated that virus removal efficacy may be subject to quality control limitations in membrane manufacture). Thus, the ROWPU is an effective barrier to water-borne pathogens. However, it is still important to avoid source water that may contain human or other animal wastes and to disinfect the ROWPU product water in order to prevent possible bacterial recontamination.

3. CONCLUSIONS. The ROWPU is a highly effective device for removing water pollutants and can provide an ample supply of assured safe drinking water if reasonable care is exercised in selection of the raw water source. It must be emphasized that the tabular data presented in this technical guide are for illustrative purposes only, and should not be used to estimate ROWPU product water quality except in the most general sense. Reverse osmosis performance depends, among other things, on the operating parameters, the choice and condition of the membrane, and the pH and temperature of the water. Knowledge of performance of the ROWPU with respect to individual source water constituents is still limited.

4. ADDITIONAL INFORMATION. Field preventive medicine personnel and others with specific health-related questions on treatment of water for both potable and nonpotable use are urged to contact the Water Supply Management Program, U.S. Army Center for Health Promotion and Preventive Medicine: phone (410) 436-3919, DSN 584-3919; Fax (410) 436-8104; email: wsmp@apgea.army.mil; home page: http://chppm-www.apgea.mil/dwater.

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Water Supply Management Program

ADDITIONAL INFORMATION, GUIDANCE, RESOURCES

MILITARY DOCTRINE AND POLICY

?? http://www.usapa.army.mil/pdffiles/l1_011.pdf : ***DA Policy Letter on Force Health Protection-Occupational and Environmental Health Hazards*** *- published by the US Army Publications Agency (June 2001)*

?? **http://www.adtdl.army.mil/atdls.htm: GEN Reimer's Training and Doctrine Digital Library** *- great way to obtain ARs, Pams, FMs, etc. Refer to this site to look up FMs /related doctrine regarding NBC topics and preventive medicine*.

?? **http://www.dtic.mil/doctrine/index.html: source library for JOINT doctrine**

USACHPPM TECHNICAL GUIDANCE AND DEPLOYMENT RISK ASSESSMENTS

?? **http://chppm-www.apgea.army.mil/desp/pages/despinfo.htm: USACHPPM Deployment Environmental Surveillance Programs website** has *information regarding field equipment, **deployment sampling kits**, ongoing **past/ongoing deployment OEH surveillance** and risk assessment projects in **Kosovo, Bosnia**, and related to the **Gulf War**. This also has/downloadable versions of various USACHPPM TG:*

- **TG 248** ***Guide for Deployed Preventive Medicine Personnel on Health Risk Management (2001)***
- **TG 230/RD 230** ***Chemical Exposure Guidelines for Deployed Military Personnel (2002)***
- **TG 236A**: ***Basic Radiological Dose Estimate - A Field Guide (2001)***
- **TG251** ***Environmental Health Field Sampling Guide for Deployments (Draft 2001)***

HAZARDOUS MATERIAL RESPONSE

?? **TICs/TIMs detector tube ordering information** http://instrumentdepot.com/tubes.htm

?? **Managing Hazardous Materials Incidents,** *US Agency for Toxic Substances and Disease Registry, Vol 1- for Emergency Medical Services, Vol 2 for Hospital Emergency Departments, and **Vol 3 is for the Medical Management Guidelines for Acute Chemical Exposures**.* http://aepo-xdv-www.epo.cdc.gov/wonder/prevguid/p0000018/p0000018.asp

?? **Pocket Guide to Chemical Hazards,** *US National Institute for Occupational Safety and Health, US Department of Health and Human Services.* http://www.cdc.gov/niosh/npg/pgdstart.html

?? **2001 Emergency Response Guidebook,** *North America (US DOT, Canada, Mexico)* http://hazmat.dot.gov/gydebook.htm

?? **Hazardous Materials Guide for First Responders** *, US Fire Adminstration - Federal Emergency Management Agency*. http://www.usfa.fema.gov/hazmat/

?? **Guide for the Selection of Chemical Agent and Toxic Industrial Material Detection Equipment for Emergency First Responders,** National Institute of Justice; Vol.1 general guide, Vol. 2 -detection equipment data sheets. http://www.ojp.usdoj.gov/nij/pubs-sum/184449.htm

CHEMICAL WARFARE AGENTS AND ASSOCIATED HEALTH GUIDELINES

?? **USACHPPM CWA and Associated Health Guidelines** *includes information and links to sites that provide information on basic chemical, physical and toxicological properties of CWA. Information on health related guidance and current environmental policy issues is also available.* **http://chppm-www.apgea.army.mil/hracp/pages/caw/home.htm**

Approved for Public Release; Distribution unlimited.

Reference Document (RD) 230

Chemical Exposure Guidelines for Deployed Military Personnel

A Companion Document to
USACHPPM Technical Guide (TG) 230
Chemical Exposure Guidelines for
Deployed Military Personnel

January 2002

U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM)

This document provides background information relevant to TG 230. The proponent of the TG and RD 230 is USACHPPM. Due to scientific advances and expanding operational needs, these documents will be updated as necessary; therefore, the user should ensure that he/she has the most updated versions.

Questions, comments, and recommendations should be forwarded to:

Commander, USACHPPM
ATTN: MCHB-TS-EES
APG-EA, 21010-5403
(410) 436-6069/DSN: 584-6069

These documents and associated information can also be obtained electronically from the following website:

http://chppm-www.apgea.army.mil/desp/

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SECTION 1 - INTRODUCTION

1.1 PURPOSE OF RD 230

Reference Document (RD) 230 provides additional details associated with the scientific rationale and assumptions behind the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) Technical Guide (TG) 230 – *Chemical Exposure Guidelines for Deployed Military Personnel* (USACHPPM, 2001). As with TG 230, this RD supercedes pervious versions which corresponded to previous TGs (i.e., TG 230A, *Short-Term Chemical Exposure Guidelines for Deployed Military Personnel* (May 1999) and TG 230B, *Draft Long-Term Exposure Guidelines for Deployed Military Personnel* (May 2000)).

TG 230 itself presents chemical concentration levels for various environmental media (referred to as Military Exposure Guidelines (MEGs)), associated health effects information, and procedural guidance to assist with operational risk management (ORM) of chemical hazards. This includes a qualitative risk assessment ranking tool that parallels existing military doctrine. For a description of the specific scope, limitations, intended audience, MEG values, and application scenarios, refer directly to TG 230.

This RD presents specific notes, equations, and sources from which the MEGs were derived. While many users may not need to be familiar with this level of detail, this RD documents the methods used so that one may clearly follow the approach used to develop or select the MEGs.

1.2 PROJECT BACKGROUND

In 1996, USACHPPM identified a broadening scope of preventive medicine concerns relating to chemical exposures during deployments. USACHPPM established a unique working group to provide the necessary input to this growing issue. This group included toxicologists, environmental health risk assessors, physicians, industrial hygienists, chemists, and environmental engineers. As a military support organization functioning as a technical representative to the Army's Office of the Surgeon General, USACHPPM is closely tied to the military community and field-level activities. In addition, USACHPPM utilized existing relationships with Joint Service related efforts to provide multi-service perspectives when developing the TG 230 (see inside back cover for specific acknowledgements).

By 1997, USACHPPM received funding support from the Army Office of the Surgeon General [for Nuclear, Biological, and Chemical (NBC) issues] to address the gap in Army preventive medicine guidance regarding "chemical" threats. Specifically, the term "chemical hazard" had begun to include not only chemical warfare agents (CWA) but also concerns regarding more common toxic industrial chemicals/materials (sometimes referred to as "TICs" or "TIMs"). The concerns were also expanding to include delayed and prolonged health effects that may not be noticeable or might otherwise not have direct and immediate impacts during the deployment. These expanded concerns have been addressed under a variety of topics to include the concept of "NBC-E", where "E" represented environment, and "low-level" exposures (a particular concern in the traditional CWA arena).

Since then, the Department of Defense (DOD) has continued to place more emphasis on the health of its military personnel during deployments under the concept of Force Health Protection (FHP). The need to identify and consider health risks to military personnel from low-level exposures to radiation or chemicals has been cited by both the scientific community as well as the military (DOD, 1999; IoM, 1999; NRC 19299). In fact, the Department of Defense Instruction (DODI) Number 6055.1, *DOD Safety and Occupational Health (SOH) Program*, August, 1998 (DOD, 1998) now specifies that environmental monitoring and risk assessments for DOD personnel in deployments outside the continental United States (OCONUS) be performed using the military ORM Process. It also specifies that "DOD Components shall develop, publish, and follow special military safety and occupational standards, rules, or regulations" that will be used to accommodate military-unique operations, workplaces, equipment and systems. This requirement allows for implementation of other DODIs such as DODI 6050.5, *DOD Hazard Communication Program*, 1990 (DODI, 1997); and DODI 6490.3 *Implementation and Application of Joint Medical Surveillance for Deployments*, 1997 (DODI, 1997).

During that time, USACHPPM attempted to address these expanding responsibilities by developing standard chemical hazard assessment guidance for deployment scenarios. In May 1999, USACHPPM published TG 230A, *Short-Term Chemical Exposure Guidelines for Deployed Military Personnel*, as its first version of this guidance – at that time only addressing short-term exposure scenarios. Later in June 2000, a final review draft TG 230B, *Long-Term Chemical Exposure Guidelines for Deployed Military Personnel*, addressing long-term (e.g. 1-year) exposure scenarios was released. These documents were to provide the military health personnel with a standard tool from which to perform field expedient chemical hazard assessments and assist with the commander's ORM process in the field.

Since that time, the political situation has continued to evolve. This has resulted in several updated and even new policies and procedures. A listing of the some of the key policies, doctrine, procedures, and guiding principles for the management of chemical hazards are listed below:

- DOD Directive 6490.2 (1997) Joint Medical Surveillance
- DOD Instruction (DODI) 6055.1 (1998) DOD Safety and Occupational Health (SOH) Program
- DODI 6050.5 (1990) DOD Hazard Communication Program
- DODI 6490.3 (1997) Implementation and Application of Joint Medical Surveillance for Deployments
- HQDA Letter 1-01-1 (2001) Force Health Protection (FHP): Occupational and Environmental Health (OEH) Threats
- Office of the Chairman of the Joint Chiefs of Staff, MCM-251-98, Deployment Health Surveillance and Readiness, 4 December 1998
- Joint Publication 3-0, Doctrine for Joint Operations, September 2001
- Joint Publication 3-11, Joint Doctrine for Operations in Nuclear, Biological, and Chemical (NBC) Environments, 11 July 2000
- Joint Publication 4-02, Doctrine for Health Service Support in Joint Operations, 30 July 2001
- Allied Command Europe (ACE) Directive 80-64, ACE Policy for Defensive Measures Against Toxic Industrial Chemical Hazards During Military Operations, 20 December 1996.

- Standardization Agreement (STANAG) 2500 NATO Handbook On The Medical Aspects Of NBC Defensive Operations AMEDP-6(B),(Feb 1996) (FM 8-9).
- USACHPPM TG 248 (2001) Guide for Deployed Military Personnel on Health Risk Management
- USACHPPM TG 244, The Medical NBC Battlebook, August 2001.
- National Science and Technology Council / Presidential Review Directive 5. (1998). A National Obligation: Planning for Health Preparedness for and Readjustment of the Military, Veterans, and Their Families after Future Deployments. Office of Science and Technology Policy, Executive Office of the President.
- National Research Council, Strategies to Protect the Health of Deployed U.S. Forces, Analytical Framework for Assessing Risks, 1999. National Academy Press, Washington, D.C.

1.3 GENERAL APPROACH

USACHPPM evaluated several different approaches to derive chemical concentration guidelines for a deployed military population. In conclusion, it was determined that use of existing guidelines and peer-reviewed toxicological estimates would the most prudent (primary) basis for the military guidelines. In some cases, source toxicity data were evaluated; however, no toxicological studies were performed by USACHPPM to specifically provide data for this project. This approach allowed for the broadest array of chemicals to be addressed in a time and cost efficient manner. In addition it ensured that the selection of guidelines was consistent with how other Federal guidelines are developed (e.g., for workers and the general population) and had already gone through scientific peer-review. To this extent, the use of previously peer-reviewed guidelines and estimates provided added quality. In all, this approach was scientifically defensible and was the most timely, monetarily feasible approach to provide guidance for already on-going field assessments.

This approach required a significant amount of media-specific, as well as chemical-specific evaluation and assumptions. These details and the specific methodologies used to derive the MEGs are described in the following sections.

1.4 LIMITATIONS OF GUIDANCE

1.4.1 Professional Judgment/Training Requirements

As discussed in TG 230, the presentation of numerical exposure guidelines does not preclude the requirement for sound professional judgment. The end result is a qualitative descriptor of risk. Users of the guidelines are expected to have a basic understanding of the methods and limitations related to the guidelines and some familiarity with potential exposure routes and toxicological effects associated with environmental exposures. USACHPPM is currently performing and developing training and software (see TG 230 Preface) for military health personnel to better accommodate these needs. Recent (FY00 – FY01) preventive medicine training sessions (6AF5 course) at the U.S. Army Medical Department (AMEDD) Center and School has demonstrated that individuals in the preventive medicine field personnel are able to learn the application of the TG 230 tool relatively quickly. Specifically, hypothetical case studies, in Appendix F of TG 230, demonstrate outcomes consistent with the developers at USACHPPM.

1.4.2 Exposure Conditions

The MEGs were developed using several "representative" exposure conditions. This was necessary to accommodate the breadth of military operations. The exposure scenarios were based on reasonably anticipated deployment conditions/durations. However, there is high probability that the true nature of exposure conditions in actual events will *not* correspond exactly to those assumed in development of the MEGs. The limitations associated with use of these exposure assumptions result in varying degrees of certainty with which the guidelines can be said to be protective. The proper use of the guidance requires individuals to find the " best fitting" guidelines.

1.4.3 Toxicity Data

These guidelines are prospective and were developed to be protective when applied as intended. These guidelines were developed using specific assumptions and are generally based on upper confidence limits of the data and include uncertainty factors (UFs). While exposures below the MEGs (for individual chemicals) would not be expected to result in the specified health effects associated with the chemical, exposures above these levels *may or may not* result in said health effects. The inability to attribute health effects to exposures above these guidelines underscores the fact that these guidelines should not be used for the retrospective assessment of health effects and can not be used to calculate or determine specific numbers of casualties.

1.4.4 Population Assumptions

The MEGs are based on the general assumption that deployed military populations consist of relatively healthy and fit male and non-pregnant female adults. Deployed military personnel are assumed to be 18 to 55 years of age, with an average weight of approximately 70 kilograms (kg) (i.e., approximately 154 pounds). In certain instances, however, the MEGs incorporate an additional level of safety to protect an identifiable sensitive subpopulation that could be anticipated in the deployed military population. While a common assumption is that military personnel will have no predisposing physical or mental factors that could exacerbate exposure to environmental chemicals, such as assumption does not appear to be entirely supported through scientific evidence. While there are basic health and fitness requirements that must be met and maintained by military personnel, an assessment of factors that can lead to chemical specific susceptibilities suggests that many of the predisposing factors such as illness (e.g. asthma), physical and emotional stressors, and life-style choices (e.g., smoking or alcohol use), and genetic traits, exist within the deployed military population (which includes active duty, reserve, and National Guard personnel). For example, the nerve agent guidelines were calculated to address the greater sensitivity of individuals that are genetically predisposed to anti-cholinesterase depression. Even though this represents a minority of the U.S. population, it is not a condition that military personnel are screened for. A specific assessment of this issue is contained in the USACHPPM White Paper entitled *The Role of Susceptibility in Establishing Exposure Standards for Deployed Troops*, C. Weese, MD, November 2001 (see Appendix F of this RD).

Despite the fact that policies dictate that pregnant women will not deploy, it is possible that a woman may not know of her pregnancy until after being placed on deployment status. Since developmental effects are of greatest concern during the first trimester, when data on developmental (fetal) toxicity and reproductive effects were available, these endpoints were also

considered and used in developing these guidelines. However, such data are not available for many chemicals.

1.4.5 Multiple Exposures/Stressors

The MEGs do not consider exposures to multiple chemicals or other non-chemical stressors such as heat stress. The toxicity of a chemical may be increased or decreased by simultaneous or consecutive exposure to another chemical or multiple chemicals, particularly those that affect the same target organ or that alter the pharmacokinetics of one or more chemicals. These issues are not typically addressed by existing federal standards and guidelines. It is noted that the Occupational Health and Safety Administration (OSHA) (29 Code of Federal Regulations (CFR) 1910.1000(d)(2)(i).) does provide a specific algorithm to address exposure to multiple chemicals. However, this quantified approach is not well-suited to the overall qualitative/ranking nature of the TG 230 deployment risk assessment approach.

Therefore, while these issues are not quantitatively addressed by the MEGs themselves, or the specific procedural guidance, the TG 230 provides a general approach to address the potential for additive or even synergistic reactions when there are multiple chemical hazards present. This concept is exemplified through various Hypothetical Case Studies in Appendix F in TG 230 so the user does not ignore these complicating factors. Consideration of other external risk factors (i.e., heavy exercise, physical stresses) are also qualitatively addressed for specific chemicals.

1.4.6 Chemicals Not Listed in TG 230

The list of chemicals addressed by TG 230 is not all inclusive of every chemical to which deployed personnel may be exposed. However, a variety of sources were used to prioritize the chemicals initially addressed by TG 230. TG 230 is a *living* document that will have a growing list of chemicals and MEGs added over time. Users are directed to USACHPPM to obtain MEGs for newly identified chemical hazards. Alternatively, users may choose to research the chemicals themselves (website sources are cited), or address the unavailability of a MEG through added uncertainties in their qualitative assessment.

Some chemical data received from routine laboratory analysis will include certain chemicals/ constituents/compounds that can be readily identified as “non-hazards”. These are primarily identified in soil or water analysis and include essential nutrients, minerals, and related compounds. They are found commonly in nature and are considered, at least at some level, beneficial or even necessary to the proper functioning of the human body. Section 3.4.1.3 describes the basis for determining such constituents in soil as “non-hazards”. Drinking water analysis also often includes constituents that may not cause toxic effects, but which may aesthetically (e.g., color, taste, odor) make the water less palatable. This could lead to reduced consumption that could in turn result in indirect health impacts from dehydration. To ensure the user considers these factors, guidelines and standards (per Technical Bulletin, Medical (TB MED) 577) are specifically identified in TG 230 (Section 1.4.4.1).

SECTION 2 – GUIDELINES FOR SHORT-TERM EXPOSURES

2.1 GENERAL ASSUMPTIONS: Exposure, Population, and Effects

2.1.1 Exposure Scenarios

Though deployments tend to span several weeks or months, there are occasions where specific operations will present unique chemical exposure hazards. Although not prolonged exposures, they may last from hours to several days. These exposures could result in significant and immediate impacts to personnel and the mission. Therefore, short-term MEGs have been provided to address these more immediate, acute exposure scenarios. Short-term MEGs should be used in the context of longer deployments (e.g. 1 year) should circumstances define a unique exposure setting of less than 14 days. If multiple short-term exposure scenarios occur consecutively, users should use long-term MEGs. Intermittent short-term exposures may require comparison to both long-term and short-term MEGs. Table RD 2-1 summarizes the durations addressed by short-term MEGs for each environmental media.

Table RD 2-1. Types of Short-term MEGs

<table>
<tr><th rowspan="2"></th><th colspan="6">ENVIRONMENTAL MEDIA</th></tr>
<tr><th colspan="4">Air</th><th colspan="2">Drinking Water</th><th>Soil</th></tr>
<tr><td rowspan="5">MEG Duration and Severity</td><td>1 hr</td><td>Minimal - no effect</td><td>Significant effect</td><td>Severe effect</td><td colspan="2">---</td><td rowspan="5">NONE – not considered to be a notable short-term hazard</td></tr>
<tr><td>8 hour</td><td colspan="3">Minimal - no effect</td><td colspan="2">---</td></tr>
<tr><td>24* hr</td><td colspan="3">Minimal - no effect</td><td colspan="2">---</td></tr>
<tr><td>---</td><td colspan="3"></td><td>5 days</td><td>5 L/day mild-no effects</td></tr>
<tr><td>14 day</td><td colspan="3">Minimal - no effect</td><td>14 days</td><td>15 L/day mild-no effects</td></tr>
</table>

* Only for specific constituents e.g., CWAs and national air criteria pollutants.

2.1.2 Population Assumptions

See Section 1.4.4.

2.1.3 Health Effects and Endpoints

Unlike the long-term MEGs, which are designed to represent a “no effect” level and/or “no significant excess cancer risk”, the short-term MEGs are based on more varied endpoints. Most of the short-term MEGs are designed to represent a minimal to no effect level (see Table RD 2-1). While the process for deriving long-term MEGs tends to incorporate standard extrapolation and factors for uncertainty, the sources used to establish short-term MEGs tend to be based on a more varied interpretation of threshold effects and the degree with which to address uncertainty. Therefore, we acknowledge the possibility of some mild effects in small

portions of the population. In addition, since there is little scientific evidence to prove otherwise, it is generally assumed that short-term exposures that do not result in immediate health effect will not result in long-term health effects. Some of the short-term values have been specifically assessed to ensure that they do not pose significant (greater than 10^{-4}) excess cancer risk (see Sections 2.2.1.2 and 3.1.5). Other, more significant health effects are also represented by a range of 1-hour Air-MEGs. The basis and details for these MEGs are described further in this section.

2.2 AIR HAZARDS – Selection of Chemicals and Guidelines in TG 230 Tables C-1 and C-2, Short-Term Air-MEGs

A list of substances to which deployed military personnel may be exposed was taken from the International Task Force (ITF-25) report of Stuempfle et al. (1998). Chemicals were ranked according to the likelihood of airborne exposures and relative toxicity. Based on continental distribution, physical properties (e.g., vapor pressure) and relative acute toxicity, these substances were categorized into groups of high, medium, and low risk. Additional substances have been added to the air list include CWAs, smokes and obscurants, riot control agents, and some pesticides. It is noted that there is an ongoing ITF initiative (ITF-40) that is re-evaluating the original ITF-25 prioritization list. It is already clear that there will be some additional high-concern constituents identified. As these, and additional, chemical constituents that are not listed are identified, USACHPPM will continue to develop MEGs. A variety of sources were used to identify the actual guidelines for the chemicals. These are described below. Substances for which existing values were not available were excluded from the tables.

2.2.1 1-hour Air-MEGs

2.2.1.1 Health Effect Levels

The 1-hour Air-MEGs were developed to delineate three major levels of health effects: minimum, significant, and severe. These guidelines are defined as follows:

- 1-hour Minimal Effects Air-MEG: The airborne concentration above which continuous exposure for 1 hour could begin to produce mild, non-disabling, transient, reversible effects, if any. Such effects should not impair performance. Increasing concentration and/or duration could result in performance degradation, especially for tasks requiring extreme mental/visual acuity or physical dexterity/strength.

- 1-hour Significant Effects Air-MEG: The airborne concentration above which continuous exposure for 1 hour could begin to produce irreversible, permanent, or serious health effects that may result in performance degradation and incapacitate a small portion of individuals. Increasing concentrations and/or duration of exposure will increase incidence and severity of effects.

- 1-hour Severe Effects Air-MEG: The airborne concentration above which continuous exposure for 1 hour could begin to produce life-threatening or lethal effects in a small portion of individuals. Increasing concentrations and/or duration of exposure will increase incidence of lethality and severity of non-lethal severe effects.

2.2.1.2 Hierarchy of Sources

The 1-hour Air-MEGs were selected from a hierarchy based on evaluation of existing values. The hierarchy and their sources are presented below.

1. AEGLs Levels 1-3 – USEPA
2. ERPGs Levels 1-3 – AIHA
3. TEELs – DOE
4. Other Sources

Each source listed above established values for a specific application. Two criteria were used in determining the priority for use as a MEG: 1) the rigor and quality of the scientific review, and 2) the appropriateness of the intended values with the military application outlined in this document. Descriptions of each guideline listed in the hierarchy are provided below.

Acute Exposure Guideline Levels (AEGLs)

The AEGLs are developed by U.S. Environmental Protection Agency (USEPA) and represent threshold exposure limits for the general public and are applicable to a range of emergency exposure periods. These values are intended to protect the general public, and include consideration of sensitive and susceptible individuals, including sensitive sub-populations but not hypersensitive or hyper-susceptible individuals (NRC 2000). AEGLs are derived for 10-minute, 30-minute, 1-hour, 4-hour, and 8-hour exposures. There are three health effect levels as defined below.

✍✍AEGL-1: The airborne concentration of a substance at or above which it is predicted that the general population, including "susceptible" individuals, could experience notable discomfort, irritation, or certain asymptomatic, non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.

✍✍AEGL-2: The airborne concentration of a substance above which it is predicted that the general population, including "susceptible" individuals, could experience irreversible or other serious, long-lasting health effects or impaired ability to escape.

✍✍AEGL-3: The airborne concentration of a substance at or above which it is predicted that the general population including "susceptible" individuals could experience life-threatening health effects or death.

The AEGL values are protective of susceptible individuals and are derived using a weight-of-evidence (WOE) method that commands a high degree of review. In addition, all AEGL Level 1 and 2 chemicals are evaluated to ensure that they do not pose an excess cancer risk greater than 1×10^{-4} (see Section 3.1.5, Carcinogenicity). Since these values are extensively peer reviewed final, interim, and proposed AEGLs published in the U.S. Federal Registry were selected first when available.

Emergency Response Planning Guidelines (ERPGs)

ERPGs, developed by the American Industrial Hygiene Association (AIHA 1999a, b), are intended for emergency planning and response operations. They are based on a WOE

evaluation and are reviewed at regular intervals as new information becomes available. Definitions of the three levels of ERPG values are as follows:

- ERPG-1: The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing more than mild, transient adverse health effects or without perceiving a clearly defined objectionable odor.

- ERPG-2: The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair an individual's ability to take protective action.

- ERPG-3: The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.

The ERPGs are intended to protect most individuals in the general population but not particularly sensitive individuals (AIHA 1999). All populations have hyper-sensitive individuals who will show adverse effects at concentrations below these guidelines. For the development of the MEGs, ERPG values were applied to a typical deployment population. ERPGs were next in the hierarchy and used if an AEGL was not available.

Temporary Emergency Exposure Limits (TEELs)

The Department of Energy (DOE) Subcommittee on Consequence Assessment and Protective Actions (SCAPA) has published TEELs for about 680 chemicals (Craig et al., 1995, 1998). They are based on the same levels set forth by the AIHA and are designed to be interim ERPGs until final ERPG values can be established. TEELs are based on the correlation between acute data [e.g., lethal concentration, 50% (LC_{50}), lowest lethal concentration (LC_{LO}), etc.] and existing values [e.g., Immediately Dangerous to Life and Health (IDLH)], Short-Term Exposure Limits (STELs), Threshold Limit Values (TLVs[?]) [TLV] and the various levels of existing ERPGs. Therefore, TEELs were used when ERPGs or AEGLs were not available.

Other Sources

- *Emergency Exposure Guidance Levels (EEGLs)* – The National Research Council (NRC)/ Committee on Toxicology (COT) (NRC, 1986 a, b) has developed EEGLs for emergency situations for deployed military personnel. 1-hour and 24-hour EEGLs have been derived for many substances. The NRC/COT defines EEGLs as:

  "A concentration of a substance in air that may be judged by DOD to be acceptable for the performance of specific tasks during rare emergency conditions."

[TLV] TLV® is a registered trademark of the American Conference of Governmental Industrial Hygienists, Cincinnati, OH. Use of this trademarked name does not imply endorsement by the U.S. Army but is intended only to assist identification of a specific product.

The NRC/COT states that the EEGL is a peak level of exposure and should not be considered as "hygienic" or "safe" (NRC 1986a). The EEGLs were developed for rare emergency conditions and, therefore, represent levels that may cause more substantial effects than the primary levels cited by the preceding sources. This level of protection was equivalent to that of ERPG-2 and AEGL-2. It is for these reasons that EEGLs were considered as Level 2 values only when ERPG or AEGL values were not available since the latter are the more recent and considered the most current available toxicological data.

✍✍*Short-term Public Emergency Guidance Levels (SPEGLs)* – SPEGLs are defined as "suitable concentrations for unpredicted, single, short-term, emergency exposure of the general public" (NRC 1986b). Reproduction and developmental endpoints are considered. The SPEGL values were considered equivalent to minimal effect levels. Few SPEGLs applicable for TG 230 were found.

✍✍*IDLH* – The IDLH values are published by the National Institute for Occupational Safety and Health (NIOSH). These represent 30-minute values that allow for a worker to escape injury or irreversible harm in the event of respiratory protection equipment failure. These values were revised in 1994 (NIOSH, 1994). Not all of these values were revised based on new toxicity information. In the 1994 revision, NIOSH made an *a priori* determination not to publish values higher than the existing values. It is for this and other reasons that IDLH values were used only when ERPG-3 or AEGL-3 values were not available. The IDLH values are often equivalent to TEEL-3 values in most instances (Craig et al. 1995).

✍✍TLVs® - *Ceiling* – For certain chemicals, the American Conference of Governmental Hygienists (ACGIH) TLVs® -Ceiling values (concentrations not to be exceeded during the 8-hr workday by workers) were considered (ACGIH 1991,1999).

✍✍*Other values that were available:* OSHA Permissible Exposure Limits (PELs) and NIOSH Recommended Exposure Limits (RELs) were not generally considered appropriate for inclusion as a criteria. However, in certain cases when toxicity information was extremely limited (particularly if they were irritant-type chemical hazards) these values were used as a basis for a minimal to no-effect level short term Air-MEG. The STELs were considered in the derivation of TEELs. However, STELs are presented for comparison purposes.

Therefore, the overall order of priority was: AEGLs > ERPGs > TEELs. The specific derivation including the criteria most important for value determination was evaluated for each substance. Appendix C of this RD includes the Air-MEGs selected, the source, and pertinent notes, to include listing any other guidelines not incorporated into the Air-MEG. Additional discussion on various exceptions to the stated hierarchy are presented below.

Special considerations were made for the specific selection of 1-hour values when conditions warranted (e.g., values based on dated toxicological information or reviews, unequal consideration of circumstances most applicable to military personnel, etc.). Some values were only applicable to a specific level of severity. For example, EEGLs were generally used to represent significant effect levels, and the SPEGLs were used to

represent minimal effect levels, where appropriate. The TLVs® - Ceiling values (ACGIH) were used to represent minimal to significant effect levels considering the criteria and the logic for which they were based. Similarly, IDLH values were used to represent either significant or severe effects 1-hour Air-MEGs, depending on the endpoints of concern, scientific rigor, and comparison to available animal study or human epidemiological data.

In some instances, the 1-hour minimal effect Air-MEGs were *less* than the 8-hr or 14-day Air-MEGs. This occurred when either: 1) there were slight differences in the professional judgment used in the original determination of the original sources values, 2) one of the original source values was derived for detection purposes (e.g., "objectionable" odor), or 3) one of the original source values was based on studies involving sensitive individuals (e.g., asthmatics).

Further exceptions to the hierarchy were made for special chemicals such as CWAs and smokes and obscurants (various Army/DOD technical reports; NRC, Committee on Toxicology, *Toxicity of Military Smokes and Obscurants, Vol. 1*, 1997a, etc.) and other situations where the published value was not consistent with the toxicological literature or with the levels set forth in this document. These exceptions are noted and explained in this RD.

2.2.1.3 CWAs

For the CWAs sulfur mustard (agent HD), the G-series nerve agents (agents GA, GB, GD, and GF) and the nerve agent VX, AEGL values are recommended as health decision criteria for deployed personnel. In addition to 1-hour short-term values there are 10-minute, 8-hour and 24 hour values as well. For completeness and to provide command with sufficient information to make well-informed operational decisions, guidelines characterizing all three AEGL levels of health effect are provided, consistent with the Air-MEGs for other toxic chemicals presented in TG 230. It is noted that other sources of CWA toxicity estimates exist but were not used for developing Air-MEGs (NRC, 1997b). These toxicity estimates include values such as LC_{50}, Incapacitating Concentration 50% (IC_{50}), and "Threshold" first-effects levels, and are specifically derived for war-time operations for casualty estimation on a gross scale. The AEGLs documented in this RD are appropriate for military *FHP* application since they provide federally-endorsed health criteria. Though designed for general population use (applicable to domestic terrorist/accident scenarios); they are not considered over-conservative for military personnel. They do address potential identifiable groups of susceptible sub-populations, but for nerve agents the identified group was individuals with abnormally low cholinesterase activity – which is a genetically based sensitivity and not screened out in the military. Therefore, the military population is similar to the general population for this particular chemical. Likewise, for HD, the key health effect of concern is on the eyes, to which there is considered to be as much human variation/sensitivity among the military population as the general civilian population. Again, the AEGLs, as conservative as some perceive them, are considered applicable to the military population. Please refer to Appendix F for additional information regarding different types of sensitive subpopulations and individual susceptibility to chemical exposures. The bottom line is that variation among the military versus that of the general population is very similar, indicating that overall physical fitness of our deployed military may not make them uniquely able to sustain greater chemical exposures before demonstrating effects.

As of the publication of this RD (January 2002), the AEGL values for HD have been finalized by the National Research Council Committee on Toxicology (NRC/COT)(Subcommittee on Acute Exposure Guideline Levels), and are awaiting publication by the National Academy Press (NRC, in press 2002). The AEGL estimates for the nerve agents have completed initial review by the National Advisory Committee on AEGLs for Hazardous Substances, and have been published in the *Federal Register* for public comment, and have now established as "interim status" (USEPA, 2001). Finalization of these proposed AEGL values for nerve agents is expected within the next calendar year.

2.2.1.4 Health Effects Levels and Hazard Severity

The three levels of health effects in TG 230 Table C-2 are consistent with the three categories presented by the AIHA/ERPG values. This provides the user with a range of concentrations from which to assess the severity of the situation. FM 100-14, *Risk Management*, lists four hazard severity levels: (1) negligible, (2) marginal, (3) critical, and (4) catastrophic. TG 230's minimal effect level delineates to FM 100-14's negligible and marginal hazard severity effect levels in which concentrations below the minimal effect levels may be considered safe for most individuals. Individuals exposed to substance concentrations between TG 230's minimal and significant effect levels correspond to FM 100-14's marginal hazard severity effect levels and may be considered to be in the marginal risk severity category where individuals may experience mild irritation or transient health effects. Individuals exposed to substance concentrations between TG 230's significant effect levels and the severe effect levels may be considered to be in FM 100-14's critical risk hazard severity effect levels where individuals may experience irreversible health consequences that would impair their ability to take protective action. Likewise, individuals exposed to air concentrations exceeding TG 230's severe effect levels are in the highest risk severity category of FM 100-14's catastrophic risk hazard severity level. Beyond this point, death may occur. Table 3-1, *Chemical Hazard Severity Ranking Chart for Military Deployments*, in TG 230 presents the relationship between health effects level and hazard severity category.

2.2.2 8-hour and 14-day Air-MEGs

2.2.2.1 General

These values were selected for continuous, 8-hour or up to 14-day exposures, consistent with a brief deployment or a brief exposure given specific information regarding source and ambient air dynamics. The potential variation in the properties and circumstances for both exposure and health effects for many substances can be significant in exposures of this duration (e.g., toxicological disposition, mode of action, environmental factors, etc.). The 8-hour and 14-day Air-MEGs represent exposure levels below which no significant adverse health effects are expected and above which the probability of adverse health effects are increased. Delineation of three levels of concern was not possible for exposures up to 14 days. The 8-hour values provide an intermediate guideline for exposure levels between the minimal effects 1-hour Air-MEG and the 14-day Air-MEG. The user is advised to review the 1-hour values to provide information of toxicity relating to concentration for a qualitative understanding of the potential slope of the dose-response curve for applications where concentrations exceed the 14-day values. The 8-hour and 14-day Air-MEGs are defined as follows:

✍✍8-hour Air-MEG: The airborne concentration above which continuous exposure for 8 hours could begin to produce mild, non-disabling, transient, reversible effects, if any. Such effects should not impair performance. Increasing concentration and/or duration could result in performance degradation, especially for tasks requiring extreme mental/visual acuity or physical dexterity/strength.

✍✍14-day Air-MEG: The airborne concentration for a continuous exposure for up to 14 days (24 hours/day) that should not impair performance and is considered protective against any significant, non-cancer effects. Increasing concentration and/or duration could result in performance degradation or increase the potential for inducing delayed/permanent disease (e.g., kidney disease or cancer).

2.2.2.2 8-hour Air-MEG Hierarchy

The hierarchy used for the selection of 8-hour Air-MEGs was as follows:

1. AEGLs Level 1 – USEPA
2. TLVs? – ACGIH

The basis for the 8-hour Air-MEGs was the 8-hour AEGL-1 values for all chemicals when available. The AEGL concept is described in Section 2.1.1.2 in more detail.

The ACGIH has published TLVs? that are health-based and consider the typical working population who is exposed 8 hrs/day, 5 days/week, 50 weeks/year for 30 years. ACGIH cautions against any other use for the TLVs?. These TLVs? are developed by the ACGIH Committee and are reviewed annually. Epidemiological data, as well as toxicological and toxicokinetic data, are used in the derivation of TLVs?. Since occupational exposures can be chronic (i.e. exceeding 7 years), cancer is considered as an endpoint. Also considered is the 2/3 (16-hour) daily break in exposure that may be important in the disposition of substances to which one is exposed in the workplace. Direct use of TLV? values were deemed suitable for 8-hour exposure and were used for 8-hour Air-MEGs for chemicals with no AEGL values. However, these values were not considered protective for continuous exposure over 24 hours to 14 days.

2.2.2.3 14-day Air-MEG Hierarchy

The hierarchy used for the selection of the 14-day Air-MEGs was as follows:

1. CEGLs – NRC/COT
2. MRLs - ATSDR
3. TLVs? – ACGIH
4. Special Considerations

✍✍Continuous Exposure Guidance Levels (CEGLs) – The NRC/COT has developed values for deployed military personnel for continuous exposures/deployments lasting up to 90 days (e.g., as in a submarine) (NRC 1986). In contrast to EEGLs, CEGLs are not for use during emergencies but rather are intended to provide guidance for persistent exposures that should not cause serious or permanent effects. These values, when available, were the first selected for the 14-day Air-MEGs.

✍✍Minimal Risk Levels (MRLs) – The Agency for Toxic Substances and Disease Registry (ATSDR) has developed acute MRLs that are appropriate for continuous exposures from 1 to 14 days (ATSDR 1996, 1997a-e). However, MRLs are derived using the no-observed adverse effect level (NOAEL) concentration and applying Ufs to extrapolate to the general population (including sensitive sub-populations but not hypersensitive individuals). The methodology used is consistent with that used by the USEPA in the development of Reference Doses (RfDs) (USEPA 1989a, 1991b). Since these values are based on a NOAEL, adverse effects may not occur as a result of exposures to concentrations that slightly exceed the MRL. It should be noted that carcinogenic endpoints were not considered in the development of MRLs. MRLs were used when CEGLs were not available.

✍✍TLVs? – While there are published methods for mathematically extrapolating TLV®s for variations in work schedules (Paustenbach 1994), none were found that addressed continuous (24-hour) exposures. Moreover, the mathematical extrapolation of values that are effects-based (i.e., a derivation of Haber's Law) may not be appropriate for strong irritants nor is this logic necessarily consistent with the determination of TLVs? (i.e., toxicokinetic data are not always available, yet a threshold was determined). Therefore, as an interim measure, the following approach was used for industrial chemicals to determine TLV? -based 14-day values. The critical endpoints used by the ACGIH in deriving TLVs? are paraphrased in Appendix D. Based on the predominant acute toxicological effects, these endpoints were categorized as "irritation-", "systemic-" or "mixed"-acting substances. Adjustments were made to all TLVs? that are systemic (or mixed) acting substances to account for differences in disposition between the 8-hour work schedule and a continuous exposure. TLVs? were adjusted from intermittent to continuous exposure by a factor of 5 days/7days, from the occupational default inhalation rate to ambient default ventilation rate by a factor of 10 m^3/20 m^3 (per day)* and for the military person's increased ventilation rate (relative to the ambient default) by the ratio of 20 m^3/29.2 m^3. A factor of 10 was applied to account for the uncertainty of extrapolating from intermittent to continuous exposure. [*NOTE: The 10 m^3/day inhalation rate represents the entire inhalation exposure volume over a day - which is assumed to be 8 hours for typical workers- to a specified contaminant. Thus, the conversion to a 20 m^3/day rate considers the full continuous 24 hours that a military person may be exposed. As such, no specific 8-hour to 24-hour conversion is necessary.] This is consistent with the logic used by the COT in CEGL extrapolation (NRC 1986). Special consideration was made for chemicals that either have a steep dose response curve with some differences between doses that cause mild and serious effects (e.g., hydrogen cyanide) or for substances that may bioaccumulate given a constant rate of exposure, though it is recognized that ambient concentrations are unlikely to be consistent. It is important to note that uncertainty has been associated with TLV®s and health effects have been noted for some worker exposures at these levels (Roach 1990). Therefore, the extrapolation using UFs is critical for developing adequately protective guidelines for the exposure scenarios presented here. TLVs? for irritants were not adjusted and, as such, were assumed to be mostly concentration-dependent. Other values, when available, are presented in Appendix D for comparison purposes. Other values developed for occupational scenarios are available (e.g., OSHA PELs and NIOSH RELs). Although these values serve regulatory purposes, TLVs? were

preferred given the methods used in their derivation, available documentation, and review that they undergo.

2.2.2.4 Summary

In summary, the order of priority for selection of 8-hour Air-MEGs was AEGLs > TLVs®. The hierarchy for the 14-day MEGs was CEGLs > MRLs > TLVs® > Special Considerations. In instances were AEGL-1 values for 8-hour exposures were more conservative than the values chosen through the hierarchy for the 14-day Air-MEGs, the AEGL-1 values were given precedence.

2.2.3 Special Airborne Chemicals and Associated Risks

2.2.3.1 Concentration-Dependent Chemicals

Effects caused by some substances (e.g., irritants) are primarily concentration-dependent and should not be time-weighted-averages (TWAs) for short-term exposures. These substances often have TLV® -Ceiling values. Since TLV® -Ceiling values denote the threshold of irritant effects, they were also considered as minimal effect values for 1-hour exposures. These TLV® -Ceiling values may be presented as 1-hour, 8-hour, and 14-day Air-MEGs where appropriate. It is noted that particularly for concentration-dependent, threshold-effect chemicals, the Air-MEGs are often the same for several duration periods (e.g., 1-hour minimal, 8-hour, and 14-day Air-MEGs).

2.2.3.2 Chemicals Absorbed Through the Skin

Some substances can be appreciably absorbed through the skin. These substances are noted with an "**s**" in the TG 230 air tables. Caution must be exercised when concentrations of these substances approach the Air-MEG since dermal absorption (to include absorption from the air itself) may contribute to the overall systemic dose and, as such, is not accounted for in these values. Specifically, airborne concentrations may be insufficient indicators of exposure because additional amounts of the chemicals can be introduced to the body via the skin.

2.2.3.3 Military-Unique Chemicals

Guidelines for some military-unique chemicals are addressed in TG 230. Specifically, guidelines were derived for CWA and various smokes and obscurants. Existing values for military-unique substances were not available from the sources previously mentioned. However, comparable values were not always available (exception AEGLs for CWA). Instead other military and NRC publications were identified. The COT has reviewed the data for many military-unique substances (NRC 1997a, and NRC 1997b). Values such as SPEGLs and EEGLs were developed by the COT for some smokes and obscurants (NRC 1997a) and were included in TG 230 using the methods described above.

2.2.3.4 CWAs

Values for many CWAs have been under active review for the development of AEGLs. As of May 2001, the AEGL values for sulfur mustard agent HD have been finalized by the

NRC/COT, (Subcommittee on Acute Exposure Guideline Levels) and are awaiting publication by the National Academy Press (NRC, 2002 in press). The AEGL estimates for the G-series nerve agents (agents GA, GB, GD, and GF) and the nerve agent VX have completed initial review by the National Advisory Committee on AEGLs for Hazardous Substances, have been placed in "Proposed" status, and have been published in the *Federal Register* for public comment (USEPA, 2001). Even though finalization of these proposed AEGL values for nerve agents will require several more months and review by the NRC/COT (Subcommittee on AEGLs), it has been determined that the proposed values for nerve agent exposure are suitable for developing deployment guidelines. The reasoning is that susceptible individuals for whom the AEGL values are designed to protect are already present in the deployed forces and are not currently being screened. For nerve agents, susceptible individuals are those with genetically determined low levels of cholinesterase as well as those with liver dysfunction, or who are taking certain common prescription drugs.

Analysis of CWA use scenarios indicates the unlikelihood of a continuous nerve agent or vesicant exposure to deployed personnel for a time period greater that 24 hours. Thus, there will be no estimate of Air-MEGs for any time period in excess of 24 hours (e.g., no CWA MEGs for time periods >1 day). For the CWAs sulfur mustard (agent HD), the G-series nerve agents (agents GA, GB, GD, and GF), and the nerve agent VX, the 24-hour estimates are provided in Table RD 2-2. AEGL values, and are recommended here as decision criteria for deployed personnel. For completeness and to provide command with sufficient information to make well-informed operational decisions, concentrations characterizing all three AEGL levels of effect will be provided in this reference document.

The estimation of a "24-hour AEGL equivalent" for each of the CWAs identified above assumes linearity of response from 8 hours to 24 hours of agent exposure, and "flat-lines" the cumulative exposure (Ct) estimate from the 8-hour AEGL estimate. Each "24 hour AEGL equivalent" is thus equal to one-third of the 8-hour AEGL estimate (in mg/m^3; conversion to parts per million (ppm) was performed by calculation, and a rounded estimate is presented). This logic is considered more protective and accurate than assuming that the cumulative exposure Ct, can be applied for both 1-hour and 24-hour exposure periods.

The values for the 14-day MEG for lewisite were derived from the Army 8-hour TWA by applying an UF of ten, and are cited as TLV[?] -Ceiling values. Please note that the vesicant lewisite is a CWA identified as requiring further consideration; it is understood that an AEGL analysis would provide a more rigorous planning estimate. Until an AEGL assessment can be performed, the interim Air-MEG for lewisite was derived from the current TWA, as outlined above. The 1-hour MEG for lewisite is cited as a ceiling value.

The CWA Air-MEGs are presented in Table RD 2-2.

Table RD 2-2. Derivation of 8-hour and 24-hour Air-MEGs for Chemical Warfare Agents

CWA CAS No.	Health Effect Level	8-hour mg/m^3 [ppm]	24-hour mg/m^3 [ppm]	NOTES
GA (Tabun) 77-81-6	MINIMAL	0.0010 [0.00015]	0.0003 [0.00005]	Based on relative potency from GB (see text for more information); (EPA 2001)
	SIGNIFICANT	0.013 [0.0020]	0.004 [0.00067]	24-hour MEG estimate derived from 8-hour AEGL by straight-line extrapolation of 8-hour AEGL Ct (see USEPA 2001 and document text)
	SEVERE	0.10 [0.015]	0.03 [0.005]	Existing (Recommended) IDLH = 0.2 (0.1) mg/m^3 (ERDEC, 1998)
GB (Sarin) 107-44-8	MINIMAL	0.0010 [0.00017]	0.0003 [0.000057]	Minimal Level: Reversible miosis, headache, eye pain, rhinorrhea, tightness in chest, cramps, nausea, malaise, miosis in human volunteers; may limit performance for night operations, aircrews, and tasks involving distance or spatial judgment
	SIGNIFICANT	0.013 [0.0022]	0.004 [0.00073]	Significant Level: Reversible miosis, dyspnea, RBC-ChE inhibition, single fibre electromyography (SFEMG) changes in human volunteers; may limit performance for night operations, aircrews, and tasks involving distance or spatial judgment
	SEVERE	0.051 [0.0087]	0.02 [0.0029]	Severe Level: Based on GB vapor experimental Sprague-Dawley rat lethality data (LC_{01}, LC_{50}) (see text for more information); (USEPA 2001) Existing (Recommended) IDLH = 0.2 (0.1) mg/m^3 (ERDEC, 1998)
GD (Soman) 96-64-0	MINIMAL	0.00050 [0.000065]	0.0002 [0.000022]	Based on relative potency from GB (see text for more information); (EPA 2001)
	SIGNIFICANT	0.0065 [0.00085]	0.002 [0.00028]	24-hour Air-MEG derived from 8-hour AEGL by straight-line extrapolation of 8-hour AEGL Ct (see USEPA 2001 and document text)
	SEVERE	0.051 [0.0066]	0.02 [0.0022]	Existing (Recommended) IDLH = 0.06 (0.05) mg/m^3 (ERDEC, 1998)
GF 329-99-7	MINIMAL	0.00050 [0.000070]	0.0002 [0.000023]	Based on relative potency from GB (see text for more information); (EPA 2001)
	SIGNIFICANT	0.0065 [0.00091]	0.002 [0.00030]	24-hour Air-MEG derived from 8-hour AEGL by straightline extrapolation of 8-hour AEGL Ct (see USEPA 2001 and document text)
	SEVERE	0.051 [0.0071]	0.02 [0.0024]	(Recommended) IDLH = (0.05) mg/m^3 (no previous existing estimate) (ERDEC, 1998)

CWA CAS No.	Health Effect Level	8-hour mg/m^3 [ppm]	24-hour mg/m^3 [ppm]	NOTES
Sulfur mustard [HD] 505-60-2	MINIMAL	0.008 0.001	0.003 [0.00033]	24-hour MEG estimate derived from 8-hour AEGL by straight-line extrapolation of 8-hour AEGL Ct (see NRC in press)
	SIGNIFICANT	0.013 0.002	0.004 [0.00067]	Existing (Recommended) GPL = 0.0001 (0.00002) mg/m³ (CHPPM, 2000b)
	SEVERE	0.27 [0.04]	0.09 [0.013]	Existing (Recommended) WPL = 0.003 (0.0004) mg/m³ (CHPPM, 2000b)
VX 50782-69-9	MINIMAL	0.000028 [0.0000026]	0.000009 [0.0000009]	(Recommended) IDLH = 2 mg/m³ (CHPPM, 2000b)
	SIGNIFICANT	0.00035 [0.000032]	0.0001 [0.000011]	Minimal and Significant Levels: Derived by relative potency from study of multiple minimal (1) or transient (2) effects in human volunteers exposed to agent GB; may limit performance for night operations, aircrews, and tasks involving distance or spatial judgment
	SEVERE	0.0013 [0.00012]	0.0004 [0.000040]	Severe Level: Derived by relative potency from study of GB vapor experimental Sprague-Dawley rat lethality data (LC_{01}, LC_{50}) (USEPA 2001). Hour Air-MEG estimate derived from 8-hour AEGL by straightline extrapolation of 8-hour GL Ct (see USEPA 2001 and document text) Existing (Recommended) GPL = 0.000003 (0.0000003) mg/m³ (ECBC, 2000) ting (Recommended) WPL = 0.00001 (0.00001) mg/m³ (ECBC, 2000) Existing (Recommended) IDLH = 0.02 (0.01) mg/m³ (ECBC, 2000)

FOOTNOTES FOR TABLE RD 2-2 – Air-MEGs for Chemical Warfare Agents

AchE: Acetylcholinesterase
AEGL: Acute Exposure Guideline Level
CNS: Central nervous system
Ct: Concentration ? time
CAS No.: Chemical Abstract Service Number
GPL: General population limit
WPL: Worker population limit
IDLH: Immediately dangerous to life and health

USEPA – US Environmental Protection Agency. 2001. *National Advisory Committee for AEGLs for Hazardous Substances; Proposed AEGL Values* Federal Register 66 (85): 21940-21964 (2 May 2001).

USACHPPM Technical Report: *Evaluation of Airborne Exposure Limits for Sulfur Mustard (HD): Occupational and General Population Exposure Criteria*, ERDEC-TR-489; April 1998, Mioduszewski et al.; *Evaluation of Airborne Exposure Limits for G-Agents: Occupational and General Population Exposure Criteria* (and February 2000 Errata Summary)

ECBC-TR-074; February 2000, Reutter et al.; *Evaluation of Airborne Exposure Limits for VX: Occupational and General Population Exposure Criteria*.

2.2.4 Ambient Air Quality

2.2.4.1 Criteria Pollutants

The USEPA uses six "criteria pollutants" as indicators of air quality and has established for each a maximum concentration above which adverse heath effects may occur. These threshold concentrations are called the National Ambient Air Quality Standards (NAAQS). The criteria pollutants are ozone (O_3), particulates [particulate matter (PM_{10}) and ($PM_{2.5}$)], carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and lead (Pb). For most of the criteria pollutants, an allowable 24-hour TWA exposure limit was established, although some have only annual averages and O_3 has 1- and 8-hour standards. Measured concentrations of the various pollutants can be compared to their respective threshold. This generates a descriptive category of air quality called the Pollution Standard Index (PSI). Once the PSI is determined, precautionary statements regarding health effects can be made.

Currently, some sampling efforts during deployments effectively monitor selected criteria pollutants. The following information was considered in preparing guidance on how to evaluate such data and the associated hazards. This information and information from the USEPA (USEPA 1998b, 1999b,c) were summarized in Section 2.2 of the TG 230.

✍✍**O_3 –** O_3 is a photochemical oxidant and the major component of smog. While O_3 in the upper atmosphere is beneficial to life by shielding the earth from harmful ultraviolet radiation from the sun, high concentrations of O_3 at ground level are a major health and environmental concern. O_3 is not emitted directly in the air but is formed through complex chemical reactions between precursor emissions of volatile organic chemicals (VOCs) and oxides of nitrogen (NOx) in the presence of sunlight. Sunlight and temperature stimulate these reactions so that peak O_3 levels occur typically during the warmer times of the year. Transportation and industrial sources emit both VOCs and NOx. VOCs are emitted from sources as diverse as automobiles, chemical manufacturing, dry cleaners, paint shops, and other sources using solvents. The reactivity of O_3 causes health problems because it damages lung tissue, reduces lung function, and sensitizes the lung to other irritants. Scientific evidence indicates that ambient levels of O_3 not only affect people with impaired respiratory systems such as asthmatics but healthy adults and children as well. Exposure to O_3 for several hours at relatively low concentrations has been found to significantly reduce lung function and induce respiratory inflammation in normal healthy people during exercise. Symptoms including chest pain, coughing, sneezing, and pulmonary congestion generally accompany this decrease in lung function. For this reason, in the past the USEPA has set O_3 standards for 1-hour and 8-hour intervals. The USEPA is transitioning to a more conservative 8-hour standard and revoking the 1-hour standard in those areas of the U.S. which are currently in attainment.

✍✍**PM –** Air pollutants called PM include dust, dirt, soot, smoke, and liquid droplets directly emitted into the air by sources such as factories, power plants, cars, construction activity, fires, and natural windblown dust. Particles formed in the atmosphere by condensation or the transformation of emitted gases such as SO_2 and VOCs are also considered PM.

Based on studies of human populations exposed to high concentrations of particles and laboratory studies of animals and humans, there are major health effects of concern. These include effects on breathing and respiratory symptoms, aggravation of existing respiratory and cardiovascular disease, alterations in the body's defense systems against foreign materials, damage to lung tissue, carcinogenesis, and premature death. The major subgroups of the population that appear to be the most sensitive to the effects of PM include individuals with chronic obstructive pulmonary disease or cardiovascular disease, influenza and asthmatics, the elderly, and children.

Annual and 24-hour NAAQS for PM were first set in 1971. Total suspended particulate (TSP) was the first indicator used to represent suspended particulates. However, since July 1987 the USEPA has used the indicator PM_{10} that includes only those particles with an aerodynamic diameter smaller than 10 microns. These particles are small enough to reach the thoracic or lower regions of the respiratory tract. Currently, the USEPA has transitioned into the use of $PM_{2.5}$ as research has supported that particles in this size range are responsible for most of the adverse health effects due to penetration into the lower regions of the respiratory tract.

Annual and 24-hour NAAQS are available for both PM_{10} and $PM_{2.5}$. An assessment of either level can be used to categorize air quality and define the PSI. It is important to note that particulates measured for ambient air quality are considered "generic" particles in that the concentration of particles is measured, but no assessment of source or composition is made. In sandy environments with high wind, particulate levels will reflect airborne sand particles, while in other settings, particulate levels might be more influenced by industrial emissions. It is also important to note that for various, specific industrial processes which generate particles, specific health-based standards may exist reflecting knowledge of the health effects of specific particles.

✍✍**CO –** CO is a colorless, odorless, and poisonous gas produced by incomplete burning of carbon in fuels. When CO enters the bloodstream, it reduces the delivery of oxygen to the body's organs and tissues. Health threats are most serious for those who suffer from cardiovascular disease, particularly those with angina or peripheral vascular disease. Exposure to elevated CO levels can cause impairment of visual perception, manual dexterity, learning ability, and the performance of complex tasks. Other major CO sources are wood-burning stoves, incinerators, and industrial sources. The CO standard is an 8-hour standard.

✍✍**SO_2 –** High concentrations of SO_2 affect breathing and may aggravate existing respiratory and cardiovascular disease. Sensitive populations include asthmatics, individuals with bronchitis or emphysema, children, and the elderly. SO_2 is also a primary contributor to acid deposition or acid rain which causes acidification of lakes and streams and can damage trees, crops, and buildings. In addition, sulfur compounds in the air contribute to visibility impairment. Ambient SO_2 results largely from stationary sources such as coal and oil combustion, steel mills, refineries, pulp and paper mills and from nonferrous smelters.

There are two health-based NAAQS for SO_2. The first is an annual arithmetic mean of 0.03 ppm [80 micrograms per cubic meter (?g/m^3)]; the 24-hour level is 0.14 ppm (365 ?g/m^3).

✍✍**NO_2** – NO_2 is a brownish, highly reactive gas that is present in all urban atmospheres. NO_2 can irritate the lungs, cause bronchitis and pneumonia, and lower resistance to respiratory infections. NO_x are an important precursor both to O_3 and acid rain and may affect both terrestrial and aquatic ecosystems. The major mechanism for the formation of NO_2 in the atmosphere is the oxidation of the primary air pollutant NO_2. NO_x, together with VOCs, play a major role in the atmospheric reactions that produce O_3. NO_x form when fuel is burned at high temperatures. The two major emission sources are transportation and stationary fuel combustion sources such as electric utility and industrial boilers. The NAAQS for NO_2 is an annual average. NO_2 can generate a PSI only if measured at levels above 0.65 ppm. A PSI over 200 ppm reflects a very unhealthy category.

2.3 DRINKING WATER HAZARDS – Selection of Chemicals and Guidelines in TG 230 Table D-1, Short-Term Water-MEGS

The chemicals included in Appendix D, Table D-1 of TG 230 were primarily taken from two sources: USEPA Drinking Water Regulations and Health Advisories (HAs) (1996), and DOD TB MED 577 (1996). All the compounds with short-term water standards in TB MED 577 were included in the list as were all the compounds with short-term Health Advisories in the USEPA document. [Note that compounds for which the USEPA has developed Maximum Contaminant Levels (MCLs) but not Health Advisories do not appear in the TG]. Seven compounds were included in Appendix D of TG 230 that were considered to be medium or high priority (Stuempfle et al. 1998). Guidelines for compounds selected from the ITF-25 list that did not have USEPA HAs or TB MED 577 standards were derived from the ATSDR acute oral MRLs.

2.3.1 Prioritization of Chemicals

Chemicals in Appendix D of TG 230 were categorized according to the likelihood of being encountered during deployments. Several sources were used for the categorization. Sources were investigated which provided prevalence of chemicals in industrial effluents (the USEPA Toxic Release Inventory (TRI)) and in effluents from superfund sites (ATSDR). Pesticides used internationally were identified using sources such as the World Health Organization (WHO) and other United Nations agencies. ITF-25 list was used to identify widely used industrial chemicals.

Compounds identified in the Table in Appendix D of this RD were divided into four categories based on these findings: High Priority, Medium Priority, Low Priority, and Unknown. While prevalence was the major factor used in prioritizing compounds, some weight was given to the toxicity of the compounds. For example, the 5-day or 2-week Water-MEGs that were less than 1 milligram per liter (mg/L) were considered High Priority compounds. Additionally, with the exception of BZ and T-2 toxin, which were not believed to be a substantial threat, all of the compounds with standards in TB MED 577 were ranked as High Priority. High Priority chemicals will vary from area to area depending on the prevalent industries and/or farm crops. Munitions and their by-products were ranked as Medium Priority because, for the most part, exposure to

substantial levels of these compounds in water is likely to be confined to the environment surrounding munitions plants.

Compounds placed in the Unknown category were not identified as prevalent compounds in any of the sources used. This does not necessarily reflect the probability of their being encountered in water. For example, there are some pesticides and industrial compounds in this category that are widely used in the U.S. and are likely to be used in industrial and agricultural practices in other areas.

2.3.2 Derivation of Short-Term Water-MEGs

2.3.2.1 General

The 5-day and 14-day Water-MEGs were developed from a selected a hierarchy and evaluation of existing values as described below. The resulting Water-MEGs are defined as follows:

- 5-day Water-MEGs: The drinking water concentration for a continuous daily consumption of either 5 L/day or 15 L/day for up to 5 days that should not impair performance and is considered protective against any significant non-cancer effects. Increasing concentration and/or duration could result in performance degradation, need for medical intervention, or increase the potential for delayed/permanent disease (e.g., kidney disease or cancer).

- 14-day Water-MEGs: The drinking water concentration for a continuous daily consumption of either 5 L/day or 15 L/day for up 14 days that should not impair performance and is considered protective against any significant non-cancer effects. Increasing concentration and/or duration could result in performance degradation, need for medical intervention, or increase the potential for delayed/permanent disease (e.g., kidney disease or cancer).

2.3.2.2 Hierarchy of Sources

Several different guidelines were used as sources for the short-term Water-MEGs. The general hierarchy was as follows:

1. TB MED 577 standards – Department of the Army
2. HAs – USEPA
3. MRLs – ATSDR
4. Other – Unique chemical concerns

Only a few of the MEGs were taken from standards published in TB MED 577. No adjustments were required for these standards, and they were adopted unmodified. For short-term standards, these included six chemicals (arsenic, cyanide, chloride, lindane, magnesium and sulfate) as well as five types of CWAs (sulfur mustard, lewisite, nerve agents, BZ, and T02 toxins). In TG 230, the nerve agents were listed by specific agent (GA, GB, GD, GF, and VX).

The majority of the Water-MEGs were derived from the USEPA 1-day and 10-day HAs. The USEPA derives HAs by dividing the NOAEL [or the lowest-observed adverse effect level (LOAEL) when a NOAEL is not available] from an appropriate human or animal study by standard National Academy of Science (NAS)/Office of Drinking Water UFs and multiplying by body weight over the daily drinking water

consumption rate [NOAEL/UF x kg body weight (BW)/L consumed]. The short-term USEPA Health Advisories were derived for a 10 kg child consuming 1 L/day. The Water-MEGs were derived using the same NOAEL and UFs used by the USEPA and a body weight of 70 kg with consumption rates of 5 L/day or 15 L/day. Note that the original source documents for the USEPA HAs were used rather than values in Drinking Water Standards and HAs table because the latter values have been rounded up or down.

A few Water-MEGs were derived from ATSDR acute oral MRLs (see Appendix E). These were adjusted for daily consumption rates in a similar fashion.

One additional chemical was added to the list using yet a separate criteria not listed in the hierarchy. A category of "lead compounds" was added to address the common findings of some level of detected "total lead" in various drinking water sources. Three existing drinking water criterion were identified: the WHO guideline of 0.05 mg/L, USEPA's MCL of 0.015 mg/L; and the U.S. bottled water criteria standard of 0.005 mg/L established in 21 CFR, Bottled Water Quality Standards, 1 April 1996. The basis for each of these values considered toxicity to children and developing fetuses. In addition, they consider long-term (chronic) exposure (consumption). However, as previously noted, military personnel are believed to consume substantial greater volumes than the 2 L/day assumption used in the derivation of these general population values. While there is limited acute lead toxicity data for adults, a Water-MEG for both short-term (2-weeks) and long-term (1 year) exposure scenarios is necessary. The proposed Water-MEG is based on the WHO 0.05 mg/L as the short-term criteria. These are considered conservative values for military applications, and may be adjusted in the future. Long-term consumption and bottled water guidance is discussed in Section 3.3.5.2.

2.3.3 The Military Adjustment Factor (MAF)

2.3.3.1 Background

The USEPA HAs were developed to protect the civilian population and incorporated UFs of ten to protect the more sensitive constituents (e.g., children, the elderly, and the infirm) of the civilian population. While we had initially considered applying a MAF of ten to the USEPA HAs to account for the more homogeneous population represented by deployed military personnel, USACHPPM decided to use a more conservative approach in adapting the Health Advisories to guidelines for the military population. Thus, the MAF was limited to three and was only applied in cases where it could be solidly justified. The rationale for using an MAF for each of the compounds to which it has been applied is discussed below.

2.3.3.2 MAF Applications

Examples of when a MAF may (or may not) be applied are as follows:

- A MAF may be used when the USEPA HA was derived from a NOAEL and the effects at the LOAEL are minimal.

- A MAF may be applied to reproductive and developmental toxicants if doing so would not introduce a risk to the developing fetus or to fertility (e.g., if developmental effects are observed only at doses toxic to the dam or at doses higher than the LOAEL of the critical study).

✍✍A MAF may be applied if short-term HAs were derived from minor effects observed at the LOAEL in subchronic and chronic studies.

✍✍An MAF will not be applied to TB MED 577 standards, carcinogens, CWAs, or compounds with steep dose/response curves.

✍✍Ammonium Sulfamate: A MAF is recommended for ammonium sulfamate because the short-term HA was based on a 90-day rat study in which only minimal effects were observed at the LOAEL (500 mg/kg/day). The only significant effect observed at the LOAEL was weight loss with no changes in organ to body weight ratios (Slight fatty degeneration of the liver was observed in one rat at the LOAEL).

Supporting data –Two other oral rat studies showed no effects at doses equal to or greater than the LOAEL of the critical study. (In the first study, no effects were seen at 500 mg/kg/day after 19 months of exposure; in the second study, no effects were seen after 105 days of exposure to 10 g/kg/day).

No data were available for mutagenicity, carcinogenicity, or developmental or reproductive effects.

A MAF of three was applied to the short-term Health Advisories for ammonium sulfamate because the short-term Health Advisory was based on a 90-day rat feeding study in which only mild effects were observed at the LOAEL.

The 1-day and 10-day Health Advisories of 75 mg/L were adjusted to 50 and 15 L consumption rates to yield Water-MEGs of 30 and 10, respectively. The values were then multiplied by the MAF of three to produce final values of 90 and 30 mg/L for 5 and 15 L consumption rates, respectively. MAFs were applied in the same fashion to the HAs for other chemicals discussed below.

✍✍Hexazinone: A MAF was applied because the short-term HA was based on a 90-day rat feeding study in which only mild effects were observed at the LOAEL.

- NOAEL = 25 mg/kg/day
- LOAEL = 125 mg/kg/day

Effects observed at the LOAEL: Weight loss, slightly elevated liver weight, increased alkaline phosphatase, decreased albumin/globulin ratio.

Supporting data – A NOAEL of 375 mg/kg/day was identified in an 8-week rat study (increased absolute and relative liver weights were the only effects observed at the LOAEL of 1500 mg/kg/day).

- Developmental effects (rat): NOAEL = 50 mg/kg/day; LOAEL = 250 mg/kg/day (effects observed: lower pup weight, no malformations).
- Developmental effects (rabbit): NOAEL (highest dose tested) = 125 mg/kg/day.

✍✍Diisopropyl methylphosphonate (DIMP)**:** The longer-term (1-year) HA for a 10 kg child was used by the USEPA for the 1-day and 10-day HAs. The critical study was a 90-day feeding study in dogs at doses of 0, 150, 1500, or 3000 ppm DIMP

in the diet (equivalent to 0, 3.75, 37.5, or 75 mg/kg/day). No effects were seen at the highest dose (75 mg/kg/day), which was considered to be the NOAEL.

Supporting data – NOAELs of 150 and 315 mg/kg/day, the highest doses tested, were observed in 90-day feeding studies conducted in rats and mice, respectively.

A NOAEL of 135 mg/kg/day (highest dose tested) was observed in a three-generation rat feeding study.

No developmental effects were observed in offspring of rats fed 0, 5, 15, or 150 mg/kg/day on days six through fifteen of gestation.

An MAF of three was applied to account for the shorter exposure duration associated with the Water-MEG. Even with this MAF, the Water-MEG for DIMP is highly conservative.

✍✍Isopropyl methylphosphonate (IMP): The longer-term (1-year) HA for a 10 kg child was used for the 1-day and 10-day HAs. The critical study was a 90-day rat-drinking water study at doses of 300, 1000, or 3000 ppm IMP in water. No effects were seen at the highest dose (3,000 ppm), which was considered to be the NOAEL.

An MAF of three was applied to account for the shorter exposure duration associated with the short-term water MEG.

No data were available for carcinogenicity or developmental or reproductive effects. Mutagenicity assays have been negative.

SECTION 3 – GUIDELINES FOR LONG-TERM EXPOSURES

3.1 GENERAL EXPOSURE ASSUMPTIONS

The following sections describe the general exposure assumptions used to calculate the various long-term MEGs presented in TG 230.

3.1.1 Exposure Duration

A continuous 1-year exposure duration was used for developing long-term MEGs. The long-term MEGs are appropriate to use for exposures exceeding 2 weeks up to 1 year. For exposures lasting less than 2 weeks, the user is referred to the short-term MEGs. Long-term MEGs, therefore, represent exposures to ambient environmental conditions such as pollution in the air, use of a continuously contaminated water supply, or persistent soil contamination. Environmental monitoring may indicate fluctuations or variations in the actual concentrations of a chemical over time. These MEGs should be compared with what is considered the most representative and generalized exposure concentration during the >2 week to 1 year period. For peaks at significantly higher concentrations for short durations, the user is referred to the short-term MEGs.

3.1.2 Exposure Frequency

It was assumed that deployed personnel would be exposed daily throughout the course of the year (365 days). Deployments lasting less than 1 year but greater than 2 weeks (it is common to have 60-, 90-, or 120-day deployments) can still be assessed using the guidelines though this provides an additional level of conservatism.

3.1.3 Population Assumptions

See Section 1.4.4.

3.1.4 Toxicological Endpoints

These guidelines address all *known* adverse health effects that could be expected to result from exposure to a given chemical of concern. Above the guideline concentrations, it is possible that a variety of health effects may occur. The types of adverse health effects and target organs associated with exposures exceeding a particular chemical guideline are described in the TG 230 appendices along with the MEGs. Because of the often limited toxicological data, there are potentially additional effects not identified. Due to various data gaps, there are several different levels of uncertainty with determining what specific dose level at which any, some, or all of the effects may actually occur. Due to human variability it is also difficult to quantify the percentage of individuals who would be impacted. For radiation and some specific chemicals (such as CWAs) there have been specific assessments yielding estimates of personnel decrement (i.e., personnel impairment to perform specific assigned tasks and percentage of troops affected) (USACHPPM, 1999b). Specifically, for CWAs, human data are available at various frank effects levels. This is often not true for other chemicals, therefore making such types of assessment extremely uncertain. While several levels of hazard severity are represented by the short-term MEGs, the long-term MEGs hazard the presumption is that the severity of effect is *negligible** if below the

guideline. The significance of the severity of effect once exposures exceeding a 1-year MEGs can be judged on the basis of short-term MEGs, though for several chemicals there is no short-term MEG available (presumably due to lack of acute data/established acute effects).

*Note: With regard to the definition of '*negligible*' effect, the long-term MEGs reflect the assumption that there are concentrations that will not cause any immediate effects or long-term, non-cancer effects, even if exposures are continuous for extended durations (i.e., 1 year). Cancer risks may be increased by any exposure to a carcinogenic chemical, but at some level that increased risk is considered acceptable. See Section 3.1.5 below. Guidelines consider both the carcinogenic and non-carcinogenic effects and ensure protection against both.

3.1.5 Carcinogenicity

Non-carcinogens are presumed to have a threshold dose below which adverse health effects will not occur. Carcinogens, on the other hand, are presumed to have non-threshold effects. Since risk from exposure to cancer-causing chemicals cannot be totally eliminated, health guidelines are traditionally based on a predetermined *de minimis* or "acceptable" risk of cancer from a chemical.

The USEPA often identifies an increased cancer incidence risk of 1-in-10,000 (or 1×10^{-4}) to 1-in-1,000,000 (or 1×10^{-6}) as an acceptable risk range of excess cancer cases over the course of a lifetime from non-voluntary exposures to environmental chemicals (NRC/FR 55 8715, Graham, 1993; Kelly, 1991; Lohner, 1997; Travis, 1987; USEPA, 1991b).). A 1×10^{-6} excess cancer risk is the more conservative end of the range and is most frequently used in decisions regarding protection of larger sectors of the general civilian population in situations where the people do not have a choice in being exposed (e.g., the Food and Drug Administration limits carcinogenic additives in food to levels that present no more than a 1×10^{-6} excess cancer risk). In contrast, many industrial standards for workplace environments offer a protection only to the 1×10^{-3} level or higher risk (e.g., a risk of 1×10^{-2}, or 1 in 100, a 1 percent chance). This higher cancer risk is "accepted" in workplace environments because it is often technologically or financially infeasible to control exposures to even lower levels and the "voluntary" nature of the exposure conditions at the workplace. The U.S. Supreme Court has upheld the industry basis for such standards (Graham, 1993).

For military operations, the level of acceptable risk will vary depending on the mission. Some situations may arise, particularly in adversarial/hostile environments, where high exposures to a relatively potent carcinogen are considered acceptable given the alternative hazards faced. However, this document establishes concentration guidelines that reflect benchmark levels below which there is no unacceptable risk associated with a cancer-causing chemical. As previously indicated, the criteria for delineating acceptable versus unacceptable excess cancer risk level used to establish these military guidelines is 1×10^{-4}. In addition to being within the USEPA acceptable risk range and being more protective than many occupational standards, the selection of this risk level is supported by previous documentation of the DOD risk level determined to be appropriate for the military (NRC, 1986b). For comparison, the background cancer rate in the U.S. is approximately 0.4 or 40% (NCI, 1999). Thus, an excess cancer risk of 1×10^{-4} increases a person's lifetime cancer risk from 0.4000 to 0.4001. Finally, since the information suggesting that a chemical exposure causes cancer is variable, the USEPA WOE classification system (i.e., alphabetical designation from A to E with A qualifying a chemical as a human carcinogen and E as evidence of noncarcinogenicity for humans).

These classifications were, therefore, provided along with MEGs in TG 230. The scheme used by the USEPA for categorizing chemicals according to their carcinogenic potential is provided below in Table RD 3-1.

Table RD 3-1. USEPA Cancer Classes

Cancer Class	Supporting Data Type
Cancer A: Human carcinogen	Sufficient evidence in epidemiological studies to support causal association between exposure and cancer.
Cancer B: Probable human carcinogen	Limited evidence in epidemiological studies (Group B1) and/or sufficient evidence from animal studies (Group B2).
Cancer C: Possible human carcinogen	Limited evidence from animal studies and inadequate or no data in humans.
Cancer D: Not classifiable	Inadequate or no human and animal evidence of carcinogenicity.
Cancer E: No evidence of human carcinogenicity	No evidence of carcinogenicity in at least two adequate animal tests in different species or in adequate epidemiological or animal studies.

3.2 AIR HAZARDS – Selection of Chemicals and Guidelines in TG 230 Table C-3, Long-Term Air-MEGs

Health effects from continuous, low-level, long-term exposures are considered differently than higher, acute (short-term) exposures. Therefore the short-term MEGs presented in Tables C-1 and C-2 of the TG 230 cannot be used to assess longer, continuous exposures. The differences resulting from exposure duration may result from toxicodynamic (specific effects and mechanisms of action) or toxicokinetic (dynamics of absorption, distribution, and elimination) processes. In addition, processes that contribute to development of cancer are more likely to occur with chronic exposure. Therefore, long-term Air-MEGs were specifically developed to address airborne concentrations of chemicals at or below which there would be no expected significant adverse health effects for the assumed maximum deployments of up to 1 year. The 1-year Air-MEG is defined as follows:

- 1-year Air-MEG: The airborne concentration for a continuous exposure up to 1 year (365 days, 24 hours/day) that is considered protective against all health effects including chronic disease and increased risk to cancer (i.e., cancer risk greater than 1×10^{-4}). No performance degradation or long-term health consequences are expected with exposure at or below this level. Increasing concentration and/or duration could increase the potential for delayed/permanent disease (e.g., kidney disease or cancer).

As previously indicated, the MEGs were developed to be protective and cannot be used to retrospectively assess risk, attribute the occurrence of health effects from a previous exposure, or estimate percentage of casualties.

3.2.1 Chemicals Listed

The initial chemical list was selected to include all contaminants for which the USEPA has developed chronic or subchronic inhalation toxicity values. Additional chemicals were incorporated in the list based on their identification through deployment environmental surveillance (Hutchens and Heller, 1999).

3.2.2 Selection of Methods

The USEPA toxicity values, referred to as RfDs or reference concentrations (RfCs) for noncarcinogenic effects and unit risks or slope factors for carcinogenic effects, are routinely used in human health risk assessment. Toxicity values are available for a number of chemicals for subchronic (defined as 1/10th of the average lifespan, or two weeks to 7 years), and chronic exposures (> 7 years) (USEPA, 1989) through oral and inhalation routes of exposure. For inhalation exposures, these values are referred to as inhalation RfCs, air unit risks (AURs), or inhalation cancer slope factors (CSFi). The primary initial sources for the inhalation toxicity values used in this section were the Health Effects Assessment Summary Tables (HEAST) (USEPA, 1997a) and the Integrated Risk Information System (IRIS) (USEPA, 1999a). All chemicals for which sub-chronic or chronic inhalation values were available from these sources were included for determination of the preliminary military air guidelines-long term (PMEGs-L).

The USEPA toxicity values were not always available for the compounds identified through deployment environmental surveillance. Therefore, exposure guidelines from other sources, including the ACGIH TLVs® (AGGIH, 1999) and the ATSDR MRLs (ATSDR, 1997a,b, c, d) were considered.

In addition, some of the carcinogenic polycyclic aromatic hydrocarbons (cPAHs) were specifically identified as common contaminants requiring exposure guidelines. As these chemicals lack HEAST or IRIS inhalation toxicity values, TLVs®, and MRLs, the USEPA National Center for Environmental Assessment (USEPA, 1994a) AUR value for benzo(a)pyrene was utilized in conjunction with USEPA provisional guidance for risk assessment of cPAHs (USEPA, 1993) to derive Air-MEGs for four of these compounds. This methodology uses toxicity equivalence factors (TEFs) to quantitatively assess the potency of each cPAH relative to that of benzo(a)pyrene. The TEF values for each of the six cPAHs are included in RD Appendix C, Table C-1. Table RD 3-2 summarizes the TEFs used.

Table RD 3-2. Toxic Equivalence Factors for Selected PAHs (USEPA, 1993)

Compound	Toxic Equivalence Factor
Benzo(a)pyrene	1.0
Benz(a)anthracene	0.1
Benzo(b)fluoranthene	0.1
Benzo(k)fluoranthene	0.01
Chrysene	0.001

The Air-MEGs were derived using the inhalation toxicity values and the guidelines discussed above. These were adjusted to more appropriately suit the conditions and exposures that military personnel might experience during a typical, long-term deployment scenario. Descriptions of the toxicity and health guidelines values, exposure assumption, and final long-term Air-MEG development and selection are described in the following sections.

3.2.3 Toxicity Values and Health Guidelines

PMEGs-L, adjusted TLVs® (TLVs®-Adj), and/or adjusted MRLs (MRLs-Adj), were estimated for all chemicals on a data-available basis (Appendix C Tables C-1 and C-2). The final Air-MEG was then derived from these guidelines.

3.2.3.1 PMEGs

The methods used for estimating the PMEGs-L are based upon those used for developing the USEPA Region III Risk-Based Concentration (RBC) Tables (USEPA, 1997b) and are consistent with the Risk Assessment Guidance for Superfund (USEPA, 1989a) methodology. The toxicity reference values for noncarcinogenic effects developed by USEPA are estimates of a daily exposure level for the human population, including sensitive subpopulations, that are without an appreciable risk of deleterious health effects (USEPA, 1989a). These values are available for a number of chemicals for subchronic and chronic exposures through oral and inhalation routes. These values are based upon animal and/or human toxicity data and critical effects, to which uncertainty and modifying factors are applied.

For the PMEGs-L estimation, RfCs in mg/m^3 were converted to an inhalation RfD in mg/kg/day by multiplying by the standard dose conversion inhalation rate (IR) of 20 m^3/day and dividing by the average weight for adults (70 kg (~160 lbs)). This calculation is shown in Equation 3-1 below. In this conversion, the 20 m^3 USEPA inhalation default is just used for the adjustment to an RfDi. The military-specific inhalation rate is later accounted for (see Section 3.2.4) when adjusting for the specific exposure variables.

Equation 3-1 – Establishing a RfD_i from a RfC

$$RfD_i = \frac{RfC \times IR}{BW}$$

The subchronic and chronic Military Risk Concentrations (MRCs) were then estimated using standard USEPA methodology (USEPA, 1989a) and military-specific exposure variables previously described. Since deployments are not expected to exceed 1 year, the subchronic RfCs presented in HEAST were considered most appropriate and used preferentially in developing the MRCs. In cases where subchronic RfCs were not available, chronic values were used.

The CSFs developed by USEPA are plausible upper-bound estimates of the probability of a response per unit intake of a chemical over a lifetime. The WOE classifications are provided along with the slope factors to characterize the extent that the available data suggest the substance is a human carcinogen. In this section, AUR values [risk per µg/m^3] were converted to inhalation CSFs in mg/kg/day^{-1} by dividing them by the average adult body weight (70 kg (or ~ 160 lbs), multiplying by the default inhalation rate (20 m^3/d), and converting from µg to mg (x 1000). Military cancer risk concentrations (Appendix C-1) were then calculated as described in Section 3.2.5.

3.2.3.2 *TLVs*? -Adj.

The TLV? - TWA, referred to as the TLV? , is defined as:

"The time-weighted concentration for a conventional 8-hour workday and 40-hour workweek, to which it is believed that nearly all workers may be repeatedly exposed, day after day, without adverse effect" (ACGIH, 1999; ACGIH 1991).

These values are based on available information including occupational experience, and experimental human and/or animal studies. The most recent (ACGIH, 1999) TLV? book was consulted for TLV? values. Where compounds were listed under "Notice of Intended Changes", the proposed new value was used to estimate the TLV? -Adj.

The TLV? s were adjusted from an intermittent to a continuous exposure and to account for the assumed military person's increased respiratory rate, as described in Section 3.2.4. A factor of 10 was then applied to account for the uncertainty of extrapolating from an intermittent to a continuous exposure.

3.2.3.3 MRLs-Adj

ATSDR defines an MRL as "an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse non-cancer health effects over a specified duration of exposure." MRLs are derived using the NOAEL level/UF approach and are below levels that might cause adverse health effects in the people most sensitive to such chemical-induced effects. MRLs are derived for oral and inhalation exposures for acute (1-14 days), intermediate (15-364 days), and chronic (365 days and longer) durations (ATSDR, 1997 a, b, c, d).

For purposes of deriving long-term MEGs, intermediate MRLs were selected over chronic MRLs when available. Acute inhalation MRLs were not considered appropriate for use in a 1-year scenario. The applicable MRL was then adjusted as described later in the next section to account for the increased respiratory rate of a military person.

3.2.4 Exposure Assumptions

3.2.4.1 PMEGs-L

The PMEGs-L were based on a set of assumptions regarding the potentially exposed individual and the defined exposure scenario. Default assumptions (USEPA, 1989a; USEPA, 1989b) were used in developing the PMEGs-L where scenario-specific data were not available.

✍✍ *BW* – The BW used to estimate the PMEGs-L was 70 kg (approximately 160 pounds). The USEPA historically uses a 70 kg BW for conducting quantitative Health

Risk Assessments (HRAs). This represents the mean BW of both adult males and females of the U.S. population. Recently, this number was updated by the USEPA's Office of Research and Development (ORD) in the *Exposure Factors Handbook* (USEPA, 1997c). Using data gathered by the National Center for Health Statistics (NCHS), the USEPA now recommends a mean adult BW of 71.8 kg.

However, existing data suggest that the overall BW of the military population is less than that of the general population because of their activity level. Using information from the USEPA *Exposure Factors Handbook* (USEPA, 1989b) it is estimated that the mean BW of adult males ranging from 18-55 years old is 78.2 kg. According to a study by the U.S. Army Research Institute of Environmental Medicine (USARIEM, 1995), the mean BW of men in the Army is 76.7 kg (n=32). Similarly for women, the mean BW for the general population is 64.6 kg for the same age group; for women in the Army, the mean BW is 61.1 kg (n=26).

Taking into account the lower BW of military personnel, a BW of 70 kg was considered reasonable for developing these guidelines and is consistent with BW assumptions used to develop most of the existing toxicity values and guidelines. An analysis also indicated this parameter does not greatly affect the final calculated guidelines (specifically, a 10 kg BW difference would not result in significant changes in final concentration guidelines). [In fact, use of the lower BW (i.e., 70 kg) results in slightly lower, more protective, MEG values]

✍✍ *IR* – The IR rate of deployed military personnel is expected to be higher than the general population because of potentially greater activity level. The USEPA has typically used an average adult inhalation rate of 20 m^3/day (USEPA 1989a; USEPA, 1991a). The recently updated USEPA *Exposure Factors Handbook* indicates somewhat lower inhalation rates of 11.3 m^3/day and 15.2 m^3/day for females and males, respectively, for long-term exposures. However, these recommendations would most likely underestimate a military person's inhalation rate (USEPA, 1989b).

The USARIEM study mentioned above provides useful information on inhalation rates based on soldier-specific activities. The authors evaluated the metabolic rate of soldiers by observing their oxygen uptake. Subjects were attired in mission oriented protective posture (MOPP) and asked to perform tasks of various intensity while their heart rate and oxygen uptake were monitored. Two different classes of MOPP were used: MOPP-0 consisting of the battle dress uniform and MOPP-4 consisting of the battle dress oversuit with gloves, boots, and an M-17 protective mask. Since deployed military personnel are most likely to be in a battle dress uniform in the long run, only data from this experimental group was used.

To evaluate energy expenditure, soldiers were asked to perform tasks with three different levels of intensity: light (<325 watts), moderate (325-500 watts) and high (>500 watts). In addition, each intensity level was broken down into different tasks. For example, the first task called L-1 involved maintaining a M-16 rifle, and L-2 referred to standing in a foxhole and performing guard duty. A higher numerical designation does not necessarily mean a higher work rate (more watts).

The USARIEM study and data presented in the USEPA *Exposure Factors Handbook* regarding activity intensity and the associated inhalation rate showed

reasonable similarity. Data from the USARIEM study were used to obtain a soldier-specific inhalation rate because the degree of ventilation can be easily related to a specific activity. The activity categories with the lowest and highest work rate for each intensity level are summarized in Table RD 3-3, below. This information was compiled from male data only.

Table RD 3-3. Estimated Ventilation and Activity Category*

Task	Description	Work rate in Watts
	LIGHT	
L-2	Standing in foxhole/guard duty	135
L-1	Maintain M-16 rifle	304
	MODERATE	
M-1	Load carriage, march 1.11 m/s, combat equipment (LBE only) with no rucksack	325
M-13	Dig defensive position	460
	HEAVY	
H-2	Load carriage, march 1.48 m/s, 20 kg load	505
H-9	Lift and carry, two 13.6 kg, 30 m, 4x/min	1162

*(USAREIM, 1995)

To estimate a daily inhalation rate, it was necessary to determine the probable daily activities of a deployed person. Since the type of activity is mission-dependent, it is not possible to pinpoint the exact number of hours a deployed person would spend on a task. Infantry personnel, however, would be expected to spend more hours performing higher intensity tasks than other personnel. The number of hours spent on some common activities is presented in Table RD 3-4.

Table RD 3-4. Hours Spent On Various Activities

Activity	Hours Spent
Sleep	4-8
Work such as digging foxholes	8
Meals	3
Evening patrol/ambush	2-4
Other light duties	1

This information was provided by a member of the military who was recently deployed to the Middle East and confirmed by another who had been deployed to Bosnia (Blanchard, 1998;Ciesla 1998). Although the number of interviewees is limited, this information is still more realistic than those assumptions used by the USEPA to derive inhalation rates for the general population. It should be noted, however, that while those who had dug foxholes considered it a heavy activity, USARIEM, as well as the USEPA, regard such activities as moderate. Results from the USARIEM report do suggest that digging foxholes is a more strenuous activity than other moderate activities. Activities such as night patrol and waiting in ambush were categorized as light as opposed to moderate.

To estimate an inhalation rate, deployed military personnel were assumed to spend 6 hours sleeping, 4 hours for sedentary activities (e.g. eating meals), 6 hours for light duties (e.g. ambush) and 8 hours for moderate duties (e.g. digging foxholes). Even though military personnel may engage in higher intensity work or obtain less sleep, the assumption that a soldier would be performing activities such as digging foxholes 8 hours a day for 365 days would balance out these conditions. Some of the intense to severely heavy activities, as described by the USEPA, include competitive cycling and long-distance running. It is unlikely that

the deployed military personnel would be engaged in tasks at such intensity levels for prolonged periods of time.

Since the USARIEM study does not include inhalation rates for periods of sleep and rest, data from the USEPA were used to fill this data gap. The recommended values are 0.4 m^3/hr and 0.5 m^3/hr for sleep and sedentary activities, respectively. For light activities, the arithmetic mean of all light intensity tasks from the USARIEM report was used as the representative value (1.2 m^3/hr). The arithmetic mean of moderate activities was computed to be 1.8 m^3/hr. However, this value was not used in the calculation of the chronic inhalation rate because, as indicated above, work such as digging foxholes requires the most energy output of this intensity level. To account for the work performed at similar intensity levels, the inhalation rate of 2.2 m^3/hr for digging defensive positions was used to represent the value for moderate activities. Only data from male subjects were used because the inhalation rate for men was greater than that for women for all tasks. This would result in more conservative soil guidelines. The final (weighted) inhalation rate used to develop the soil guidelines was derived as shown in Equation 3-2.

Equation 3-2 – Weighted Inhalation Rates

$$IR_{daily} = \left(\frac{0.4 m^3}{hr} \times \frac{6 hrs}{day}\right) + \left(\frac{0.5 m^3}{hr} \times \frac{4 hrs}{day}\right) + \left(\frac{1.2 m^3}{hr} \times \frac{6 hrs}{day}\right) + \left(\frac{2.2 m^3}{hr} \times \frac{8 hrs}{day}\right)$$

This results in a daily inhalation rate of 29.2 m^3/day. This value is much higher than the USEPA *Exposure Factors Handbook* recommended value of 15.2 m^3/day for long-term exposures for males and is somewhat higher than the average adult USEPA default value of 20 m^3/day (USEPA, 1989b).

✍✍*Exposure Duration (ED)* **–** The duration of deployments can vary but is not expected to exceed 1 year. Therefore, an ED of 1 year was assumed to derive the long-term Air-MEGs. The PMEGs-L may be used to conservatively assess exposures of shorter duration (for exposures of less than 14 days, see USCHPPM TG 230) but were not designed to address continuous exposures exceeding 1 year.

✍✍*Exposure Frequency (EF)* – An exposure frequency of 365 days per year was assumed in developing the PMEGs-L, which address the continuous, daily inhalation of ambient air during a 1 year deployment.

✍✍*Averaging time (AT)* **–** The intakes from longer-term exposure to noncarcinogenic toxicants are evaluated by averaging intakes over the period of exposure (i.e., subchronic or chronic daily intakes). The averaging time for a noncarcinogen (ATn) is ED x 365 days, and is in units of days. The intakes for carcinogens are calculated by prorating the total cumulative dose over a lifetime (i.e., lifetime average daily intake or chronic daily intake). The assumption for carcinogens is that a high dose received over a short period of time is equivalent to a corresponding low dose spread out over a lifetime. The averaging time for a carcinogen (ATc) is 25550 days, based on a 70-year lifetime (70 years x 365 days per year) (USEPA, 1989a).

3.2.4.2 *TLVs*? -Adj

The TLVs?, which are human inhalation values, were adjusted from an intermittent work week schedule (5 days/week) and a default occupational ventilation rate (10 m^3/8 hours) to a continuous exposure (7 days/week) and an ambient default inhalation rate (20 m^3/24 hours). Thus, the TLV? was adjusted by 5 days/7days and 10 m^3/ 20 m^3 (USEPA, 1994b). They were then further adjusted to consider the soldiers increased respiratory rate of 29.2 m^3/day by a factor of 20 m^3/29.2 m^3.

3.2.4.3 MRLs-Adj

Because of the 1-year maximum ED, intermediate (subchronic) inhalation MRLs were used in preference to chronic inhalation MRLs whenever available. The MRL was then adjusted by a factor of 20 m^3/29.2 m^3 to consider the soldiers increased respiratory rate.

3.2.5 Methods for Developing PMEGs-L, Adjusted TLVs?, and Adjusted MRLs

3.2.5.1 PMEGs-L

The methods used to estimate sub-military risk concentrations (MRCs), chronic-MRCs, and military cancer risk concentrations (MCRCs) are based on those used to develop the USEPA Region III Risk-Based Concentration Tables (USEPA, 1997b). Adjustments to the methodology consider the increased INHALATION rate of a soldier, the potential duration and frequency of exposure, and the assumption that the deployed soldier population does not include children. Subchronic RfCs were used preferentially to chronic RfCs when available. The target hazard quotient (THQ) was set to 1.0 and the target cancer risk (TCR) was defined as a 1:10,000 increased incremental risk of developing cancer (1×10^{-4}). A TCR of 1×10^{-4} is typically used in risk assessment for industrial scenarios and was considered reasonable for subchronic exposures in a healthy military population. The resultant MRCs and MCRCs for each chemical were then compared and the lowest (i.e., the one protective for both carcinogenic and noncarcinogenic effects) was identified as the PMEG. The RfCs, CSFis, MRCs, MCRCs and estimated PMEGs-L are presented in Appendix C.

For Ambient Air – All RfCs were converted to RfDs and all AUR were converted to CSF_i (where CSF_is or RfD_is were not specifically provided) as previously described.

Equation 3-3 – MRCs for Ambient Air

$$MRC = \frac{THQ \times RfD_i \times BW \times AT_n}{EF \times ED \times IRA}$$

Equation 3-4 – MCRCs for Ambient Air

$$MCRC = \frac{TCR \times AT_c}{EF \times IFA \times CSF_i}$$

Where:

- AT_n = Averaging time noncarcinogens = ED * 365 days/year = 365 days
- AT_c = Averaging time carcinogens = 70 * 365 days/year = 25550 days
- BW = Body weight = 70 kg (see IFA, below)
- CSF_i = carcinogenic slope factor inhalation, compound-specific = $(mg/kg\text{-}day)^{-1}$
- ED = Exposure duration = 1 year (see IFA, below)
- EF = Exposure Frequency = 365 days/year
- IFA = Inhalation factor
  (ED * IRA)/ BW = (1 year * 29.2 m^3/day)/ 70 kg = 0.417 m^3*y/kg*d
  (Modified from USEPA Region III's IFAadj that includes both children and adults)
- IRA = Inhalation rate = 29.2 m^3/day (see IFA, above)
- RfD_i = Reference dose inhalation, compound-specific = mg/kg-day
- TCR = target cancer risk = 1 x 10^{-4}
- THQ = target hazard quotient = 1

3.2.5.2 TLVs[?] -Adj

The TLV[?] was adjusted from intermittent to continuous exposure by a factor of 5 days/7 days, from the occupational default inhalation rate to ambient default ventilation rate by a factor of 10 m^3/20 m^3 (per day)* and for the military person's increased ventilation rate (relative to the ambient default) by the ratio of 20 m^3/29.2 m^3. A factor of 10 was applied to account for the uncertainty of extrapolating from intermittent to continuous exposure. [*NOTE: The 10 m^3/day inhalation rate represents the entire inhalation exposure volume over a day - which is assumed to be 8 hours for typical workers- to a specified contaminant. Thus, the conversion to a 20 m^3/day rate considers the full continuous 24 hours that a military person may be exposed. As such, no specific 8 hour to 24 hour conversion is necessary.] The TLVs[?] for irritants were assumed concentration dependent and were, therefore, not adjusted.

Equation 3-5 – Adjusted TLVs[?]

$$TLV_{adj} = TLV \times \left[\frac{5}{7} \times \frac{10}{20} \times \frac{20}{29.2} \times 0.1\right] = TLV \times 0.024 \text{ or } \frac{TLV}{40.9}$$

3.2.5.3 MRL-Adj

The intermediate MRL was adjusted to account for the military personnel increased inhalation rate by multiplying by the ratio of the general population inhalation rate over the estimated military inhalation rate.

Equation 3-6 – Adjusted MRLs

$$MRL_{adj} = MRL \times \left(\frac{20}{29.2}\right) \times MRL \times 0.68$$

3.2.6 Air-MEG Selection

PMEGs-L, TLVs®-Adj and MRLs-Adj were estimated for each chemical for whichever of the identified toxicity values and exposure guidelines were available. The comparison of all three values (where available) gave the most complete picture of existing standard exposure levels (Appendix C, Table C-2). The final Air-MEG selection considered the specific population and exposure scenario and was based on the following general hierarchy: PMEGs-L > TLV®-Adj > MRL-Adj (Appendix C, Table C-3).

The PMEG was selected as the first tier in the hierarchy because the USEPA toxicity values available for many environmental contaminants were developed for continuous exposures, and the toxicity values have undergone significant review. Furthermore, the USEPA exposure assessment methodology is easily adjusted for varying exposure scenarios. The TCR can also be readily adjusted to account for an occupational (healthy worker population) exposure that was considered more appropriate to the scenario under consideration. In addition, the actual duration of exposure, military inhalation rate, and absence of a child population were easily accounted for.

The TLV®-Adj was selected as the second tier of the hierarchy because TLV®s were available for many compounds and were developed for a worker population. Using a UF of 10 to adjust from intermittent to continuous exposure, and adjusting for a military person's inhalation rate, should provide an air concentration level that nearly all military personnel can be exposed to day after day without adverse health effects. It is important to note that uncertainty has been associated with TLV®s and health effects have been noted for some worker exposures at these levels (Roach 1990). Therefore, the extrapolation using UF is critical for developing adequately protective guidelines for the exposure scenarios presented here.

The MRL-Adj was selected as the third tier of the hierarchy for this exposure scenario because MRLs were available for fewer chemicals and were developed to protect the general population, including sensitive subpopulations such as children and the elderly, to whom this guide does not apply. Though the PMEGs-Ls are also based on toxicity parameters which are protective of a general (including sensitive) population, the toxicity parameters are designed to be adjusted for various exposure conditions and have been more widely accepted as "standards." Furthermore, unlike the PMEGs-L and TLVs®, the MRLs do not consider carcinogenic effects.

Whenever more than one preliminary exposure level was estimated, the levels were compared with each other to identify any marked differences. Differences less than an order of magnitude were generally considered insignificant because of the uncertainty involved in the derivation of the numbers and the use of UFs of up to 3000. In such cases, the hierarchy (PMEG > TLV®-Adj > MRL-Adj) was followed. However, if the hierarchy resulted in a MEG that was less protective (such as by less than an order of magnitude) the data were briefly reviewed to determine that a scientifically plausible reason for the difference exists and that the hierarchy-derived MEG would be adequately

protective. If the chemical was an irritant without systemic effects (within a reasonable range of the doses under consideration), and the effects were principally concentration- rather than time-dependent, supporting data were reviewed to assess if one of the higher preliminary exposure levels was more appropriate for selection as the MEG (e.g., ammonia).

If the differences between the PMEG, TLV® -Adj and/or the MRL-Adj were greater than an order of magnitude (either higher or lower) the chemical was marked for further evaluation. Supporting toxicological data were reviewed and the most appropriate value selected as the MEG. The MEGs, their basis, and the rationale for the selection of each MEG is provided in Appendix C-Table C-3.

3.2.7 General Air Quality Standards – Tables C-4 and C-5 in TG 230

As discussed in TG 230, the USEPA identifies six "criteria pollutants" as indicators of basic ambient air quality and has established for each of them a maximum concentration above which adverse health effects may occur. These concentrations are called the NAAQS (USEPA, 1999b). The criteria pollutants include CO, NO_2, SO_2, O_3, particulates (PM_{10} and $PM_{2.5}$) and Pb. The sources of these pollutants include factories, power plants, incinerators, automobiles, construction activity, fires and windblown dusts.

The analyses for these compounds are more routinely being accomplished during deployment missions, and in many environments it has been demonstrated that the ambient concentrations of these pollutants (particularly for particulate matter PM_{10}, $PM_{2.5}$) exceeds the USEPA NAAQ "standards." However, many larger cities/areas in the continental US also frequently, if not routinely, exceed the NAAQS. In CONUS, NAAQS evaluations provide for an overall "index" of air quality that can be used to make location specific advisories to the public in terms of protecting health (USEPA, 1999c). The standards are designated for different averaging durations, for example different pollutants are designated in some cases for a 3-hour average, 8-hour average, 24-hour average, quarterly average and/or annual mean. In attempting to make comparisons to the USEPA criteria standards during deployments, the USACHPPM has noted that these criteria pollutants are of particular concern for sensitive sub-populations such as the elderly, children, or those who have pre-existing health conditions such as cardiovascular or lung disease. However, military personnel are exposed continuously to ambient air concentrations rather than predominately indoor air concentrations as with the general population and will have increased physical activity and resulting higher ventilation rates as compared to the general population. An effort has been made to establish MEGs for pollutants included in the NAAQS that are consistent with the intent of other MEGs derived for the TG. Specifically, the MEGs are desired to be adequately protective of the military population for 24 hours per day, up to 1 full year.

The USEPA has not developed RfCs or RfD_i for these substances. Only the NAAQS (primary), which were developed to protect the general public, are provided by USEPA (see below). However, the NAAQS do provide appropriate estimates of reasonable air concentrations of pollutants. Therefore, they have been considered on a case-by-case basis in choosing an appropriate guideline for military use. Annual mean, quarterly averages, or 24 hour NAAQS were considered when available. Linear extrapolation was used for substances only with standards for 8-hour averages. Since the second tier of the TG 230 hierarchy for deriving MEGs is ACGIH worker TLV® -TWAs, they were also taken into consideration when choosing an appropriate MEG. The TLVs®, as designated in Table RD 3.5, were adjusted for adjusted military IR rate [(and EF/ED as previously

described and were compared to the NAAQS. Table RD 3.6 lists the TLV? -Adj. values and the proposed MEGs for these pollutants.

Table RD 3-5. Non-Adjusted NAAQS and TLV? -TWAs

POLLUTANT	NAAQS (Primary)	ACGIH TLV-TWA*
Carbon Monoxide (CO) 8-hour Average 1-hour Average	9 ppm (10 mg/m^3)** 35 ppm (40 mg/m^3)**	25 ppm (29 mg/m^3)**
Nitrogen Dioxide (NO_2) Annual Arithmetic Mean	0.053 ppm (100 µg/m^3)**	3 ppm (5.6 mg/m^3)**
Ozone (O_3) 8-hour Average	0.08 ppm (157 µg/m^3)**	0.08 ppm (moderate work) (0.16 mg/m^3)**
Lead Quarterly Average	1.5 µg/m^3	0.05 mg/m^3*** 0.03 mg/m^3****
Particulate < 10 ?m (PM-10) Annual Arithmetic Mean 24-hour[a]	50 µg/m^3 150 µg/m^3	10 mg/m^3 (inhalable particulate)
Particulate < 2.5 ?m (PM-2.5) Annual Arithmetic Mean 24-hour[b]	---- 15 µg/m^3 65 µg/m^3	3 mg/m^3 (respirable particulate)
Sulfur Dioxide (SO_2) Annual Arithmetic Mean 24-hour Average 3-hour Average	0.03 ppm (80 µg/m^3)** 0.14 ppm (365 µg/m^3)** 0.50 ppm (1300 µg/m^3)**	2 ppm (5.24 mg/m^3)**

* The TWA concentration for a conventional 8-hr workday and a 40-hr workweek, to which it is believed that nearly all workers may be repeatedly exposed, day after day, without adverse effect.
** Parenthetical value is an approximately equivalent concentration.
*** This is also the OSHA 8-hr PEL (29 CFR 1910.1025)
**** OSHA action level (29CFR 1910.1025). For those workers exposed to air concentrations at or above the action level for more than 30 days, OSHA mandates periodic determination of blood lead levels.
[a] 3-year average of the 99th percentile of 24-hour concentrations over a given year.
[b] 3-year average of the 98th percentile of 24-hour concentrations over a given year.

Table RD 3-6. Proposed Long-Term Air-MEGs for NAAQS Pollutants

Criteria Pollutant	TLV? -Adj./TWA-Adj.	Long-Term MEGs*
Carbon Monoxide (CO)	0.61 ppm (0.71 mg/m^3)**	3 ppm (3.3 mg/m^3)**
Nitrogen Dioxide (NO_2)	0.073 ppm (0.14 mg/m^3)**	0.053 ppm (0.1 mg/m^3)**
Ozone (O_3)	0.002 ppm (0.004 mg/m^3)**	0.027 ppm (0.052 mg/m^3)**
Lead (Pb)	0.001 mg/m^3***	0.0015 mg/m^3
Particulate < 10 ?m (PM_{10})	0.24 mg/m^3 (inhalable particulate)	0.07 mg/m^3
Particulate < 2.5 ?m ($PM_{2.5}$)	0.07 mg/m^3 (respirable particulate)	0.04 mg/m^3
Sulfur Dioxide (SO_2)	0.05 ppm (0.13 mg/m^3)**	0.05 ppm (0.13 mg/m^3)**

* Based on evaluation of NAAQS.
** Parenthetical value is an approximately equivalent concentration.
*** This is also based equivalent to an adjusted OSHA 8-hr PEL (29 CFR 1910.1025)

3.2.8 Uncertainty, Modifying Factors, and Special Considerations

Uncertainties involved in the development of the long-term MEGs are principally those related to exposure parameters and toxicological data. Exposure assumptions include such factors as specified inhalation rates and BW, a continuous exposure of 365 days/year, and an ED of one year maximum. These values may or may not represent those found in the actual deployment scenario. Furthermore, ambient air concentrations of chemicals are highly unlikely to remain constant.

Uncertainty in the toxicological data may result from data gaps, insufficient quality or quantity of data and/or lack of human data. The USEPA addresses these uncertainties in developing their RfDs (for noncancer effects) by applying uncertainty and modifying factors to a critical study NOAEL or LOAEL. The UFs consist of multiples of ten (values less than ten are sometimes used) to account for variation in the general population (including sensitive subpopulations), to extrapolate from animals to humans (interspecies variability), to derive a chronic RfD from a subchronic study, and when a LOAEL is used instead of a NOAEL. A modifying factor of up to ten may also be applied to reflect a qualitative professional assessment of additional uncertainties in the critical study and entire database not specifically addressed by the UFs. ATSDR develops MRLs in a similar manner, using a NOAEL approach and UFs. Thus, the uncertainty associated with a RfD/RfC or a MRL may span an order of magnitude or greater. The USEPA toxicity values and the ATSDR MRLs were developed to protect the general population, including sensitive subpopulations, and their use in developing exposure guidelines for subchronic exposures by healthy military populations may be conservative (overly protective).

As previously discussed (section 3.1.5), the approach to address carcinogenicity followed that of the USEPA. The target cancer rate for deriving the PMEGs-L has been set at 1×10^{-4} as described. This approach involves an upper-bound estimate of the slope of the dose-response curve, the extrapolation model, and various assumptions about carcinogenesis that may or may not be correct for each chemical. For instance, the assumptions historically made by USEPA for carcinogenic risk assessment would not be appropriate for chemicals that have a threshold for response or for substances for which the likelihood of effects is highly dependent on the age of the individual at exposure.

The TLVs® are based on available information including occupational experience, experimental human and/or animal studies. The basis on which these values are established may differ from substance to substance, as the amount and nature of the information considered in establishing the TLV®. Consequently, the precision of the estimated TLV® is also subject to variation (ACGIH, 1999; ACGIH, 1991). The TLVs® do not routinely incorporate all of the standard USEPA/ATSDR-like UFs; however, they typically have some margin of safety and are designed to protect "nearly all workers". The extrapolation from intermittent to continuous exposure to develop a TLV®-Adj results in additional uncertainty. The extensive number of compounds for which long-term MEGs are required and the data gaps that exist for many chemicals preclude the routine use of a biologically–based model, such as the physiologically-based pharmacokinetic (PBPK) model, in deriving long-term MEGs at this time. The use of a TLV®-Adj for continuous exposure and a soldier's increased respiratory rate, with the application of a UF, is believed to provide adequate protection for a 1-year military personnel exposure scenario and has precedence in USEPA risk assessment

methodology. However, because of data gaps relative to pharmacokinetics, the health and safety professional in the field should be alert to potential symptoms of exposure when applying any guidelines derived from intermittent exposures to continuous long-term exposures.

3.2.9 Specific Chemicals – Hexachloroethane versus Hexachloroethane Smoke

It is important to note that the MEG for hexachloroethane refers to chemical hexachloroethane (perchloroethane) and *not* hexachloroethane smoke (HC smoke). The inhalation toxicity of hexachlorethane smoke is attributed to the production of zinc chloride ($ZnCl_2$), the major component of the smoke. The NRC has established a military Permissible Exposure Guideline Level (PEGL) of 0.2 mg/m^3 for $ZnCl_2$. This PEGL (NRC, 1997) was established based on an approximation of 50 8-hr exposures during a 2-year tour of duty. It is not appropriate to apply the hexachloroethane MEG levels for evaluating exposures to HC smoke. Exposures to smokes and obscurants are being evaluated as part of a separate initiative.

3.2.10 Specific Chemicals – Selection of the MEGs Outside of Hierarchy

- *Benzene* – The MEG for benzene is 0.04 mg/m^3 based on the TLV® -Adj. The PMEG and TLV® were both cancer-based; the MRL was based on neurotoxicity. Review of the data used to establish the MRL suggested that the exposure dose and endpoint used to develop the MRL were overly conservative for development of a MEG, especially considering UFs and that the statistics were not particularly robust. The concentrations evaluated in the study were 0.00, 0.78, 3.13 and 12.52, and a level of 0.78 was used to develop the MRL. The endpoints used to develop the MRL were increased forelimb grip strength and increased frequency of rapid response, as identified by t-tests (an Analyses of Variance (ANOVA) followed by a pair-wise analysis would have been more robust) and U- tests. The number of trials was not specified. It was not felt that these endpoints were indeed adverse effects for the purpose under consideration. Furthermore, removal of all UFs for the MRL would have resulted in a value similar to the PMEG and almost two orders of magnitude higher than the TLV® -adj. The MRL Human Equivalency Concentration (HEC) was 0.33 ppm, to which a UF of 90 was added. The next higher dose level (3.1 ppm) endpoint was increased forelimb grip strength and decreased rapid response frequency and was considered for our purposes a minimal LOAEL, and resulted in a HEC of 1.3 ppm, with an UF of 90 (0.015 ppm). Conversion to mg/m^3 and adjustment for a military person's respiratory rate resulted in an MRL-adj of 0.032 mg/m^3. Considering the UF of 90, this value was considered indistinguishable from the TLV® -adj and the TLV® -Adj, was considered protective of non-cancer and cancer effects. The PMEG was not considered adequately protective for neurological effects.

- *Toluene* – The MEG selected for toluene is 4.6 mg/m³ (1.2 ppm) based on the TLV® -adj. The PMEG was not selected because it was considered too conservative for the exposure being addressed. The PMEG was based on a chronic RfD developed from an 8-hour TWA with a UF of 300 (intended to protect sensitive populations). As the effects of toluene are more concentration- than time-dependent, the conversion from an occupational to chronic exposure likely resulted in additional conservatism.

The unadjusted TLV® (188 mg/kg or 50 ppm) was considered borderline in its protectiveness as it appeared to be a LOAEL in some studies and is actually equivalent to an AIHA ERPG-1. However, because of the greater concentration dependency of the compound and the safety factor of ten used in developing the TLV® -adj (resulting in increased conservatism when converting from a occupational to continuous exposure), the adjusted TLV® -Adj value of 4.6 mg/m³ (1.2 ppm) was considered adequately protective and adopted as the MEG. The new draft ATSDR guidelines for inhalation of toluene are 4 ppm (acute) and 0.4 ppm (chronic), resulting in a chronic MRL of 1.5 mg/m^3 and a MRL-adj of 1.02 mg/m³. The adjusted MRL is within the designated range (one order of magnitude) of the adjusted TLV® , but was not considered as appropriate because it was based on a chronic MRL for protection of sensitive individuals.

✍✍*Ethyl benzene* **-** A MEG of 2.95 mg/m³ was established based on the (intermediate) MRL-adj. for developmental (skeletal) effects. The PMEG and the MRL were both based on the same study and endpoint. However, the PMEG was considered overly conservative due to the incorporation of a UF of 10 related to lack of multigenerational reproductive and chronic studies that did not seem applicable to a shorter-term exposure. The TLV® -adj was based on irritation and was considered less protective for developmental effects. Furthermore, the adjustment used for conversion from occupational to continuous exposure was questionable due to the pharmacokinetics of ethyl benzene.

✍✍*Naphthalene* – The MEG for naphthalene is 0.0071 based on the MRL-adj. There is wide variation between the TLV® -adj, and the MRL-adj and PMEG (which are quite similar). The MRL-adj was selected over the PMEG because the PMEG considered UFs that were more applicable to chronic exposures. There are some data in the ATSDR toxicity profile suggesting that for those with G-6-PD deficiencies neither the TLV® nor the TLV® -adj may be adequately protective. Although the MRL-adj value is considerably more protective than the TLV® -adj., the dose at which G-6-PD deficient persons may develop toxic effects is not known. Based on the ATSDR 1998 toxicological profile for naphthalene, adequate data to develop a dose-effect for hematological and cataract effects in humans is not available, and there are substantial species differences. Considering that G-6-PD deficiencies are not presently screened for prior to deployment (Weese, 2001), and that this deficiency occurs in approximately 10 percent of black males (Italians, Greeks and other people from the Mediterranean basin are also more prone to this disease) the potential seriousness of the effect, and the possibility of potential exposure to compounds with additive effects, a higher (less conservative) MEG cannot be justified without additional data.

✍✍*Polycyclic Aromatic Hydrocarbons (PAHs)* **–** Inhalation toxicity data was lacking for the following PAHs: acenaphthene, acenaphthylene, anthracene, fluoranthene, fluorene, phenanthrene, and pyrene. Oral RfD data were available for acenaphthene, anthracene, fluoranthene, fluorene, and pyrene. Oral to inhalation route extrapolation without additional UFs was used to develop PMEGs for these compounds. For acenaphthylene and phenanthrene, Quantitative Structure-Activity Relationships (QSAR) developed on the TOPKAT™ system were obtained. RfD estimates were based on TOPKAT estimates of rat chronic LOAEL data and uncertainty factors according to USEPA guidelines.

TOPKAT™ System designed by Health Designs, Inc., Rochester, N.Y. Use of this trademarked name does not imply endorsement by the U.S. Army but is intended only to assist identification of a specific product.

✍✍*Styrene* – The PMEG value of 2.05 mg/m^3, based on neurotoxicity, was selected as the MEG for styrene. This value was in line with the hierarchy and almost identical to the TLV® -adj (2.08 mg/m^3) based on neurotoxicity but derived from different data sets. The MRL was considered overly conservative because it was a chronic value based on the same data as the PMEG, differing essentially by a UF of ten that was applied because of different interpretations of a NOAEL vs. a minimal LOAEL (i.e., an UF of 100 versus an UF of ten).

✍✍*N-Hexane* – All three preliminary exposure levels were based on neurotoxicity. The TLV® -adj of 4.31 mg/m^3 (which was not substantively different from the MRL-adj) was selected as the MEG and was considered slightly more appropriate than the MRL-adj (derived from a chronic MRL) for the exposure under consideration. The PMEG was not selected because it was based on the same data as the MRL-adj but was considered overly conservative due to an additional uncertainty factor (100 vs. 300). It is noteworthy that of the hexanes, only the n-hexane isomer appears substantially neurotoxic.

✍✍*Xylene* – The TLV® -adj and the MRL-adj were within an order of magnitude of each other and the hierarchy was followed. TLV® -adj of 10.6 mg/m^3 or 2.44 ppm was selected for the MEG. Although the values were based on different endpoints, the MRL had an UF of 300, and the TLV® -adj was almost two orders of magnitude lower than the less serious LOAEL (developmental) on which the MRL was based.

3.3 DRINKING WATER HAZARDS – Selection of Chemicals and Guidelines in TG 230 Table D-2 – Long-term Water MEGS

Short-term Water-MEGs for deployed military personnel are presented in USACHPPM TG 230. However, health effects from continuous, low-level, long-term exposures may be different than those produced by higher, acute (short-term) exposures to the same chemicals. In addition, health effects from long-term exposures may occur at substantially lower doses than those resulting from acute exposures. The long-term Water-MEGs were specifically developed to address drinking water concentrations for chemicals at or below which no significant adverse health effects would be expected for the average military person during deployments of up to one year. The 1-year Water-MEG is defined as follows:

✍✍1-year Water-MEG: The drinking water concentration for a continuous daily consumption of either 5 L/day or 15 L/day for up to 1 year that should not impair performance and is considered protective against all health effects including chronic disease and increased risk to cancer (i.e., cancer risk greater than 1 x 10^{-4}). Increasing concentration and/or duration could increase the potential for delayed/permanent disease (e.g., kidney disease or cancer).

The guidelines were developed to be protective and should not be used to retrospectively assess or attribute the occurrence of health effects from a previous exposure.

3.3.1 Sources of Chemicals

Chemicals included in the long-term Water-MEGs table include: (1) those with long-term standards in the TB MED 577 (DA, 1999); (2) compounds that were detected in water by environmental sampling in Bosnia; and (3) compounds that were identified as a high priority in RD 230, Appendix D**.** A number of compounds that have short-term MEGs do not have long-term guidelines. Such compounds include the CWAs and related compounds (GA, GB, GD, VX, BZ, EA 2192, sulfur mustard, lewisite, and T-2 toxin). For these compounds, long**-**term Water-MEGs have not yet been developed primarily because extended contamination of water with these compounds is considered improbable.

3.3.2 Hierarchy of Sources

The long-term Water-MEGs were derived using a hierarchy process of selecting from existing health-based guidelines and toxicity values. These include the following in descending order of priority:

1. TB MED 577 standards – Department of the Army
2. HAs – USEPA
3. MRLs – ATSDR
4. HEAST RfDs – USEPA
5. Region III (RBC Table oral RfDs – USEPA
6. Other - Unique chemical considerations

With the exception of TB Med 577 water quality standards, all values were adjusted with military exposure assumptions. The TB MED 577 provides field water quality standards for long-term (7-days to 1-year) exposure to six substances (arsenic, cyanide, chloride, lindane, magnesium, and sulfate). These standards were adopted unchanged as the long-term Water-MEGs. If the TB MED 577 standard for any one of these chemicals is exceeded, the water cannot be used as a potable supply. With the exception of the TB MED 577 standards, the long-term MEGs are not standards and should not be used to approve or disapprove field drinking water supplies. For the remaining chemicals, the existing USEPA and ATSDR guidelines were adjusted to address military drinking water consumption rates. Adjustments were also made to better accommodate the specific military population and anticipated deployment scenario exposures. These resulted in adjusted HAs (HA-Adj), MRLs-adj, and adjusted chronic/subchronic RfDs (RfD-Adj).

3.3.3 Toxicity and Health Effect Assumptions

The toxicity information included along with the long-term Water-MEGs was obtained from a variety of toxicity databases. The resulting guidelines and toxicity assumptions used to establish the long-term Water-MEGs have different levels of UF built in and, with the exception of TB MED 577 Field Drinking Water Standards (FDWS), exposure to concentrations somewhat above the long-term Water-MEGs may not cause any adverse health effects. The actual concentration above which one or more of the listed health effects may occur is highly variable due to several factors including the type of chemical, the steepness (slope) of the dose-response curve, the actual quantity of contaminated water consumed, exposure through other sources such as inhaled air, exposure to other chemicals which may cause additive or synergistic effects, and unique individual

susceptibilities. The following sub-sections describe the underlying toxicological basis for each of the toxicity/health guidelines used in the MEG hierarchy.

3.3.3.1 DOD Tri-Service Military FDWS

TB MED 577 provides FDWS for long-term (7-days to 1-year) exposure to six chemicals (arsenic, cyanide, chloride, lindane, magnesium and sulfate). These standards were developed for the soldier consuming either 5 or 15 L of water per day for temperate and arid climates respectively and were adopted unchanged as the long-term Water-MEGs**.** Because they do not include UFs to protect members of the general population who may be unusually sensitive to the effects of chemicals, the DOD Tri-Service standards are less conservative (i.e., less protective) than the long-term MEGs derived from the USEPA Health Advisories or from other sources (e.g., ATSDR MRLs, USEPA RfDs). However, no adverse health effects should be experienced if the concentration of a chemical substance in water is equal to or lower than the concentration indicated by the MEG and if the water is consumed for no more than the specified time period.

The TB MED 577 Standards were derived primarily to prevent performance degradation in the battlefield. As mentioned above, a UF to protect more sensitive members of the population were not incorporated into any of these standards. In some cases, concentrations just slightly higher than the standard may elicit adverse health effects so it is important that the standards not be exceeded. The approach used in their development is described by Daniels J.I. (Daniels, 1988). The basis for each of the six standards is summarized below.

1. Arsenic – The arsenic standard was derived from a NOAEL of 0.32 milligrams per day (mg/day), which was based on the absence of effects in a human population sustained by arsenic-contaminated well water for up to 10 years. No UFs were applied.

2. Chloride – The standard of 600 milligram per liter (mg/L) for chloride was based on the potential for rejection of drinking water due to lack of palatability. It was estimated that, at this level, two percent of the soldiers would refuse to drink the water, risking dehydration, and 12 percent would complain about the bad taste. The fraction of the soldiers refusing to drink the water would increase with the chloride concentration. Because taste was the only health effect considered, the same standard was set for drinking water consumption rates of 5 L and 15 L. No UF was applied.

~~3.~~ Cyanide (CN) – Toxic levels of cyanide in the drinking water were calculated from the levels of cyanide (CN) in the blood shown to be associated with no adverse health effects in humans. The safe level of blood CN was taken from measured concentrations of cyanide in blood drawn from patients receiving the drug sodium nitroprusside to reduce blood pressure during surgery. From these data, it was estimated that 0.5 mg CN per liter (CN/L) whole blood was the threshold level for changes in blood chemistry and that clinical symptoms of cyanide intoxication were likely above 2 mg/L. Using a pharmacokinetic model, the amount that would have to be ingested in drinking water to reach a level of 0.5 mg CN/L in whole blood was calculated. Because CN is rapidly degraded in the body, the standard was based on the quantity of CN in drinking water that would be consumed during a short time interval rather than by dividing the threshold level by the total quantity of water consumed during a 24-hour period. The Daniels et

al. report concluded from their review of the literature, that protection from the acute effects of CN in drinking water should protect military personnel from suffering from chronic CN toxicity.

4. Lindane – The standard for lindane was based on the lowest dose to cause adverse effects in 3-day human studies. A UF of ten was applied to the LOAEL of 30 mg/day to reduce the concentration to a NOAEL. No other UFs were applied to the human data. This extrapolation was supported by two chronic oral studies in which 50 milligram per kilogram (mg/kg) in the diet was administered to rats. One of these studies identified a NOAEL of 1.25 mg/kg/day and the other identified a LOAEL of 2.5 mg/kg/day based on increased liver weight and slight liver and kidney damage.

5. Magnesium – The standard for magnesium was designed to prevent laxative effects which could cause performance degradation. Such effects can occur at water concentrations just slightly higher than the standard. Since chronic effects from exposure were not identified, the short-term (7 days) and long-term (1 year) standards are identical. No UF was applied.

6. Sulfate – Similar to magnesium, the standard for sulfate was designed to prevent laxative effects. The concentration set by the standard is the lowest dose that will not cause diarrhea. Since chronic effects from exposure were not identified, the short-term (7 days) and long-term (1 year) standards are identical. No UF was applied.

3.3.3.2 USEPA Health Advisories-Adjusted (HA-Adj)

About half of the long-term Water-MEGs were derived from the USEPA longer-term HAs for adults. The USEPA HAs are non-enforceable, recommended drinking water quality guidelines for exposure durations of 1 day, 10 days, longer-term, or a lifetime. The longer-term HA is defined by the USEPA as “the concentration of a chemical in drinking water that is not expected to cause any adverse noncarcinogenic effects up to approximately 7 years (10 percent of an individual's lifetime) of exposure, with a margin of safety”. The USEPA longer-term HAs are based on the weight of a 70-kg adult consuming two liters of water each day, but also incorporate an added tenfold UF to ensure protection of the more sensitive members of the general population including children and the elderly. These assumptions (sensitive populations and moderate drinking water consumption rates) do not accurately reflect the anticipated deployment scenario conditions. Adjustments to account for the maximum military consumption rates described below.

3.3.3.3 ATSDR adjusted MRLs (MRLs-Adj)

The ATSDR has derived short-term/acute (1-14 days), intermediate (15-364 days), and chronic (365 days and longer) oral MRLs. Intermediate oral MRLs, when available, were used for the compounds that were not addressed in TB MED 577 and for which there were no USEPA longer-term HAs. The methodology used for development of the MRLs is based on non-carcinogenic health effects and is similar to that used by the USEPA for development of HAs. As with the USEPA HAs, tenfold UFs (often multiples of them) are incorporated into the MRLs to adjust for (protect) the more sensitive members of the exposed population. Thus, the MRLs also have a built-in margin of safety and exposure to a level up to tenfold greater than the MRL will not necessarily cause adverse health effects. The oral MRLs are

expressed as daily human doses in units of mg/kg/day that are "safe" for the given exposure conditions. These MRLs were adjusted to account for the military exposure scenario using the assumptions discussed in the next section.

3.3.3.4 USEPA RfD-adjusted (RfD-Adj)

For chemicals that have no existing long-term (2-week to 1-year) health guidelines, the USEPA subchronic or chronic RfDs were used to calculate the MEG. About 20 percent of the long-term water MEGs were derived from subchronic and chronic RfDs. Because RfD values are designed to be protective for the general population (like the HAs and MRLs, there are several "UFs" incorporated into them) and they are designed to reflect exposure over 7 years to a lifetime, some of the long-term MEGs derived from these values tend to be quite conservative. Subchronic RfDs were taken from the USEPA HEAST (USEPA, 1997b). Chronic RfDs were taken from IRIS or the Region III RBC Table (USEPA, 1997d). These guidelines also include an UF to provide protection for the more sensitive members of the human population.

3.3.3.5 Cancer Assessment

In line with the logic described in Section 3.1.5, drinking water concentrations associated with a 1×10^{-4} or lower excess risk of developing cancer were considered acceptable for the carcinogenic chemicals included in TG 230. The concentration of the carcinogens that pose a 1×10^{-4} excess risk of cancer with continuous exposure for a 70-year lifetime were obtained from two sources: The USEPA Drinking Water Regulations and HAs (ATSDR, 1996), and from IRIS (USEPA, 1999a). Risk-specific concentrations for five compounds (alachlor, beryllium, chlorothalonil, dibromchloropropane, and TCDD) were present in the HA document but not in IRIS. The risk-specific concentration for benzo(a)pyrene was taken from IRIS where it had been up-dated since its first appearance in the HAs. The risk-specific concentrations for the remainder of the carcinogens were the same in the HA document and IRIS.

To assess whether the long-term Water-MEGs for the carcinogenic compounds are protective against cancer as well as non-carcinogenic effects, the 10^{-4} risk-specific concentrations of those compounds were compared with the long-term Water-MEGs derived from non-cancer endpoints. To do this, the risk-specific concentrations in drinking water (mg/L) were multiplied by 70 years/1 year to estimate the concentrations in water that would pose the same cancer risk for an exposure duration of 1 year as the life-time exposure. An adjusted risk-based concentration was then derived by multiplying this time-adjusted value by 0.4 (2/5) to convert it from a drinking water consumption rate of 2 L/day to 5 L/day (see equation 3-7; (Appendix D, Table D-2). The adjusted drinking water 10^{-4} risk-specific concentration was then compared with the 5 Liter MEG derived from non-carcinogenic endpoints. If the adjusted risk-specific concentration was equal to or greater than the non-cancer-based 5 L MEG, the MEG was considered to be protective against cancer. If the adjusted drinking water, risk-specific concentration was lower than the 5 Liter MEG derived from non-carcinogenic endpoints, then the adjusted drinking water risk-specific concentration was selected as the MEG. This analysis indicated that the long-term Water-MEGs selected on the basis of non-carcinogenic endpoints according to the hierarchy described above for beryllium and hexachlorobenzene were not protective against cancer. The adjusted 10^{-4} risk-specific concentrations was adopted as the long-term Water-MEGs for beryllium and the adjusted MRL was adopted as the long-term Water-MEGs for hexachlorobenzene (see Section 3.3.5.2

for decision logic). These long-term Water-MEGs are protective against both carcinogenic and non-carcinogenic effects. The non-cancer based long-term Water-MEGs were protective for all other carcinogens included in TG 230.

Equation 3-7 – Adjusted CRCs

$$CRC_{adj} = \frac{CRC \times AT_c \times DWR_{GP}}{DWR_{MP}}$$

Where:

CRC_{adj}	=	Adjusted cancer risk-specific concentration (mg/L)
CRC	=	Cancer risk-specific concentration (mg/L)
DWR_{GP}	=	Drinking water rate (2 L/day) for the general public
DWR_{MP}	=	Drinking water rate (5 L/day) for military personnel
ATc	=	Averaging time for carcinogenic substances (70 years/1 year)

3.3.4 Exposure Assumptions

Depending on the type of toxicity value/health guidelines used to develop a MEG, different exposure assumption adjustments were necessary. These types of adjustments were made to ensure overall consistency with the general military exposure assumptions described in Section 2.1. As previously indicated, an ED of 1 year and EF of 365 days/year were assumed when deriving these guidelines. Similarly, the BW of 70 kg was used to derive the long-term Water-MEGs. Drinking water consumption rates had to be adjusted from those of the general public to those expected for deployed military personnel. Adult members of the general public are considered to drink an average of 2 L water per day. Maximum daily water consumption rates for deployed military personnel vary from 5L /day in temperate climates to 15 L/day in arid climates. To remain combat effective, the maximum individual daily amount of drinking water required by deployed military personnel can range from about 5 to 15 L/day depending on climate, season, intensity of work, and type of battlefield (e.g., conventional, in which chemical, biological, or nuclear attack is not anticipated) (Directorate of Combat Developments, 1983; Headquarters, DA, 1983). These daily maximum consumption rates are consistent with the experiences of the Israeli Defense Forces and observations by U.S. Army Medical Services Officers at National Guard armor battalions training exercises in the Mojave Desert (Henry, 1985). Exposure assumption adjustments made to each toxicity value/health guidelines are summarized below.

3.3.4.1 DOD FDWS

The DOD long-term FDWS were developed assuming a 70 kg adult weight and were designed for exposures of 7 days to 1 year. In addition, they were developed assuming the military-specific consumption rates of 5 L/day (temperate climate) and 15 L/day (arid climate). No exposure adjustments were necessary.

3.3.4.2 Adjusted HAs (HAs-Adj)

The HAs are expressed as water concentrations in units of mg/L. Since the HAs are based on a 2 L/day drinking water consumption rate, the HAs had to be adjusted for the two military drinking water consumption rates of 5 L /day and 15 L/day (See Equation 3-8). Depending on the underlying health effect of concern, further adjustments may be made in the future.

Equation 3-8 – Adjusted Health Advisories

$$HA_{adj} = \frac{HA_{LT} \times DWR_{GP}}{DWR_{MP}}$$

Where:

HA_{adj}	=	Adjusted Health Advisory (mg/L)
HA_{LT}	=	Longer-term Health Advisory (mg/L)
DWR_{GP}	=	Drinking water rate (2 L/day) for the general public
DWR_{MP}	=	Drinking water rate (5 or 15 L/day) for military personnel

3.3.4.3 MRL- and RfD- Based Long-term Water-MEGs

The oral MRLs and USEPA RfDs are expressed as daily human doses in units of mg/kg/day. To convert them to military water concentrations, they were multiplied by 70 kg and divided by 5 L or 15 L to produce MRL- or RfD based long-term MEGs for the two rates of drinking water consumption (5 or 15 L/day) (see Equations 3-9 and 3-10). Depending on the underlying health effect of concern, further adjustments may be made in the future.

Equation 3-9 – MRL-based Water-MEGs

$$MRL_{MEG} = \frac{MRL \times BW}{DWR_{MP}}$$

Where:

MRL_{MEG}	=	MRL-based MEG (mg/L)
MRL	=	Minimal Risk Level (mg/kg/day)
BW	=	Adult body weight (70 kg)
DWR_{MP}	=	Drinking water rate (5 or 15 L/day) for military personnel

Equation 3-10 – RfD-Based Water-MEGs

$$RfD_{MEG} = \frac{RfD \times BW}{DWR_{MP}}$$

Where:

RfD_{MEG}	=	Adjusted RfD (mg/L)
RfD	=	Reference dose (mg/kg/day)
BW	=	Adult body weight (70 kg)
DWR_{MP}	=	Drinking water rate (5 or 15 L/day) for military personnel

3.3.5 Water-MEG Selection

As previously stated, various methods and guidelines were used to establish the list of long-term water MEGs presented in TG 230. The final long-term water MEG selection considered the specific population and exposure scenario and was based on the following hierarchy: DOD FDWS > USEPA HA-Adj **≥** ATSDR MRL-Adj> USEPA RfD–Adj. With the exception of the FDWS, the hierarchy also considered a cancer assessment and if necessary, a cancer-based value would supercede the stated hierarchy if more protective at the 1×10^{-4} risk level. [Note that the FDWS are all protective against unacceptable excess cancer risk according to the criteria discussed in Section 3.1.5.]

3.3.5.1 Uncertainty

The uncertainties described in Section 3.2.8 for the Air-MEGs were developed according to USEPA methodology using the UF/RfD approach. These UFs apply to the derivations for water guidelines as well. With the exception of FDWS, all of the guidelines from which the long-term Water-MEGs were developed were based on the USEPA approach of applying UFs to NOAELs or LOAELs from studies in animals or humans. Additional uncertainty is introduced by the estimation of water consumption rates that may vary considerably from person to person and from day to day. While concentrations of chemicals in water may vary less than those in air, it is probable that considerable variation will occur over a period of a year for chemicals originating in water from sources related to human activities. The TB MED 577 standards were not derived using the UF/RfD approach except that a UF of 10 was incorporated into the standard for lindane that was based on a LOAEL from a short-term human study. Because the FDWS were all were derived from studies in humans, there is no uncertainty associated with extrapolation from the toxic response of animals to those of humans. However, with the exception of arsenic that was based on long-term effects in humans, they were derived from short-term human exposures, and there may be some uncertainty as to the effects from long-term exposures.

3.3.5.2 Unique Chemical Concerns

Special considerations were taken in the derivation of several of the chemicals in this TG. For two chemicals (diazinon and terbufos), errors were found in the source

documents that affected the derivation of the Water-MEGs. The hierarchy described above was not appropriate for four of the chemicals (carbon disulfide, hexachlorobenzene, TCDD, and vanadium) for which long-term Water-MEGs were developed. Finally, for the remaining compound (ethylene dibromide) guidelines based on non-cancer endpoints were not available. Many Polycyclic Aromatic Hydrocarbons (PAHs) have limited toxicity data (cancer and non-cancer), so a relative potency approach was utilized in developing Water-MEGs. In addition, controversial and/or questionable toxicity concerns associated with the metals lead and copper resulted in a unique basis for Water-MEGs. These unique chemical considerations and their resolutions are discussed below:

✍✍*Carbon disulfide*

The only available long-term guideline for exposure to carbon disulfide is the subchronic HEAST RfD of 0.1 mg/kg/day which equates to 1.4 mg/L for a water consumption rate of 5 L/day. This value was found to be higher than the acute MRL which was based on a l4-day oral (gavage) study in mice (LOAEL = 3 mg/kg/day) while the HEAST subchronic RfD was based on a developmental toxicity inhalation study in rabbits (NOAEL = 11 mg/kg/day). Even though it is tenfold lower than the RfD, the acute MRL was used as the source of the MEG because it was derived from a study that used the more relevant route of exposure.

✍✍*Diazinon*

The MEG (0.007 mg/L) developed from the longer-term HA was selected even though the adjusted HEAST subchronic RfD (0.0126 mg/L) and the adjusted Region III RBC (0.0126 mg/L) were higher. (The adjusted subchronic or chronic RfDs should theoretically be lower than the longer-term HA since they are targeted for longer exposure periods.) In the HEAST Table, the NOAEL for Diazinon is reported as 0.09 mg/kg/day. This value was taken from a subchronic rat study by Davies and Hollub (NCI, 1999) in which the NOAEL was reported to be 9 microgram per kilogram per day (?g/kg/d) based on depressed cholinesterase levels at higher doses. The NOAEL of 9 ?g/kg/day converts to 0.009 mg/kg/day, not 0.09 mg/kg/day as reported in HEAST. Applying the UF of 100 reported in HEAST produces a subchronic RfD of 0.00009 mg/kg/day. This equates to a drinking water value of 0.0013 mg/L for a daily 5 L consumption rate. While lower than the HA-adj, the HA-adj of 0.007 mg/L which is based on a 52-week monkey study was used as the MEG.

✍✍*Ethylene dibromide*

Exposure guidelines based on non-cancer endpoints have not been developed for ethylene dibromide. While a 1-year adjusted 10^{-4} cancer risk-specific concentration (0.0012 mg/L) is available, further information must be evaluated to ensure that the MEG derived from the adjusted cancer risk specific concentration is protective against health effects other than cancer. Comparison of the unadjusted, lifetime 10^{-4} cancer risk (0.00004 mg/L) with the USEPA MCL of 0.00005 mg/L shows that the two values are virtually identical. The MCL is defined as the maximum permissible level of a contaminant in water which is delivered to any user of a pubic water system and, as such, should be protective against both cancer and non-carcinogenic health effects. Thus, the adjusted cancer risk specific concentration was adopted as the MEG.

✍✍*Hexachlorobenzene*

The adjusted HA (0.08 mg/L) could not be used as the MEG because it is higher than the adjusted cancer risk-specific concentration (0.06 mg/L). Likewise, the MEG could not be derived from the cancer risk because it was not protective against non-carcinogenic health effects. The adjusted intermediate MRL of 0.0042 mg/L was used for the MEG even though it is 2.7 fold lower than the adjusted RfD (0.0112 mg/L). The RfD was based on liver effects in a three-generation rat study conducted in 1985 while the MRL was based on effects on the ovary observed in a 90-day study in monkeys. The study on which the MRL was based was published in 1993 and was not available in 1987 when the HA and RfD were developed (USEPA, 1987a). To be fully protective against reproductive effects, the MEG was derived from the MRL.

✍✍*TCDD*

Two non-cancer based guidelines, the MRL-adj (2.8 $x10^{-7}$ mg/L) and the HA (1.4 $x\ 10^{-8}$), were available for TCDD. Both are lower than the adjusted-cancer-risk-specific concentration (6 $x\ 10^{-7}$ mg/L). The intermediate oral MRL was based on a NOAEL of 0.005 ?g/kg/day from a 90-day feeding study in guinea pigs in which decreased thymus weight and BW gain occurred at the LOAEL. A UF of 30 was applied. The HA was based on a LOAEL of 0.001 microgram per liter (?g/L) from a three-generation reproduction study in rats. Effects seen at the LOAEL included reduced gestation index, decreased fetal weight, and increased incidence of dilated renal pelvis. The HA was selected as the MEG because of the potential reproductive effects.

✍✍*Terbufos*

The HA for Terbufos was based on the RfD. This value was reported as 0.00013 mg/kg/day in the Summary Table in the document Drinking Water Regulations and Health Advisories (USEPA, 1996a) but as 0.000025 mg/kg/day in the original HA source document (USEPA, 1987b). The latter value is compatible with the RfD reported in HEAST and was used to derive the MEG.

✍✍*Vanadium*

The adjusted HEAST subchronic RfD (0.098 mg/L) was two times higher than the adjusted ATSDR intermediate oral MRL (0.042 mg/L). The RfD was based on the absence of renal effects observed at the NOAEL of a lifetime study in which vanadyl sulfate was administered to rats in the drinking water. The MRL was based on the observation of minor renal effects (increased plasma urea, and mild histological changes) in a study in which sodium vanadate was administered to rats in the drinking water for three months. The NOAEL was 0.3 mg/kg/day. The UFs of 100 were used in both studies. Because effects on the kidney were seen in the three-month study at a dose lower than the NOAEL observed in the lifetime rat study, the adjusted ATSDR MRL was adopted as the MEG.

✍✍*Polycyclic Aromatic Hydrocarbons (PAHs)*

Guidelines based on carcinogenic or non-carcinogenic effects were not available for four carcinogenic PAHs (benzo[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, and chrysene) included in the TG. As discussed, cancer-based guidelines were determined for each of these compounds using toxic equivalence factors (TEFs). In addition, guidelines determined in this manner were compared with guidelines derived from RfDs developed for total petroleum hydrocarbon (TPH) fractions by (Edwards et al.). To err on the conservative side, the lower of the two values was adopted as the MEG. In the TPH method, an RfD of 0.03 mg/kg/day was assigned to the components of the aromatic fraction of

TPH with carbon numbers falling between 17 and 21. This value was based on the established RfD for pyrene which was considered to be a conservative surrogate because it has a lower carbon number than any of the other compounds in the fraction. The values for benzo[k]fluoranthene and chrysene derived from the surrogate RfD were lower than those derived with the TEF method and were selected as the MEG.

✍✍*Lead*

As described in Section 2.3, a category of "lead compounds" was added to address the common findings of some level of detected "total lead" in various drinking water sources. Three existing drinking water criterion were identified: the WHO guideline of 0.05 mg/L, USEPA's MCL of 0.015 mg/L; and the U.S. bottled water criteria standard of 0.005 mg/L established in 21 CFR, Bottled Water Quality Standards, 1 April 1996. As previously described, despite the fact that military personnel are believed to consume substantial greater volumes than the 2 L/day assumption used in the derivation of these general population values, these criteria are considered conservatively protective since the basis for each of these values considered toxicity to children and developing fetuses. The current proposed long-term MEG in Table D-2 is based on the USEPA action level (MCL) of 0.015 mg/L. Approved bottled water sources should contain less than 0.005 mg/L of lead as a matter of 'regulation', but as long as levels are in accordance with the selected MEGs there is not expected to be a health concern. These are considered conservative values for military applications, and may be adjusted in the future.

✍✍*Copper*

There is indication that copper, particularly elemental copper, is not a significant toxic constituent. Elemental copper (CAS 7440-50-8) itself is an essential element and therefore *deficiencies* can result in adverse health effects. The major soluble salts (e.g., copper (II) sulfate, copper II chloride) are believed to have greater toxicity, but there are conflicting reports of the overall quantified levels of significance for both acute as well as chronic, long-term ingestion. Some evidence suggests some acute (e.g., abdominal, GI tract) effects at extremely high levels – but it is confounded by presence of other heavy metals. Chronic mice and rat data indicate potential for liver and kidney damage. There are USEPA as well as several State drinking water standards for copper. These range from 1.0 – 1.3 mg/L. These values appear to be quite conservative considering the scientific literature (HSDB, website 2001). A value of 1.0 mg/L was selected for the long-term copper MEG value. It reflects the low-end of the range of existing criteria to somewhat address the increased consumption rate for military. These are considered conservative values for military applications, and may be adjusted in the future.

3.3 Soil Hazards - Selection of Chemicals and Guidelines in TG 230 Table E

The long-term Soil-MEGs were derived using the general USEPA health risk assessment (HRA) guidance used for environmental cleanup efforts (USEPA, 1989a). Specific 'safe' soil concentration levels were established by back-calculating from accepted health target levels (no effect for non-cancer compounds and acceptable cancer risk for cancer-causing compounds as discussed in Section 3.4 and 3.5). Some

chemicals may have both noncancer and carcinogenic effects. For these compounds, soil concentrations determined from both effects were compared and the lower concentration used as the final soil level for that chemical. If a chemical is not suspected to be carcinogenic, then the MEG was based on its noncancer effect. The 1-year Soil-MEG is defined as follows:

✍✍1-year Soil-MEG: The soil concentration for continuous, daily exposure (from ingestion, dermal absorption, and inhalation) for up to 1 year (365 days) that should not impair performance and is considered protective against all health effects including chronic disease and increased risk to cancer (i.e., cancer risk greater than 1×10^{-4}). Increasing concentration and/or duration could increase the potential for delayed/permanent disease (e.g., kidney disease or cancer).

Subsequent sections discuss the selection of methodology for determining soil levels, toxicity data, and exposure assumptions used to develop the MEGs.

3.4.1 Selection of Chemicals

The chemicals selected for evaluation are consistent with those used to develop drinking water guidelines. This is because health risks from both media involve ingestion of the contaminated media as the primary exposure pathway.

3.4.1.1 Exceptions

Exceptions to this rationale are the CWAs which were not included in the development of water guidelines due to their instability in water (USACHPPM, 1999c). The persistence of chemical agents in soil is dependent on various environmental conditions such as, but not limited to temperature and soil moisture. Studies have shown that CWAs are, in general, not persistent when applied to surface soils. However, since chemical agents do not readily undergo hydrolysis in soil as they do in water, encounters with CWA-contaminated soil is a potential pathway for exposure. In addition, studies have indicated that sulfur mustard (HD) does not undergo natural degradation if buried in soil (USACHPPM, 1999c). Therefore, Soil-MEGs were established for the CWAs.

3.4.1.2 Chemical Exposures From Soil Not Addressed by the Soil-MEGs

Some chemicals, such as dimethyl methylphosphonate, are not expected to adsorb to soil (HSDB, 1999). When available information clearly indicated that a chemical does not bind readily to soil, a Soil-MEG was not established. Other examples include chloride, magnesium, and sulfate which were included in the drinking water list because they have assigned field drinking water standards (DA, 1999). The primary health concern associated with these chemicals is that they can cause dehydration either by military personnel's refusal to drink water due to poor taste or because of the chemical's acute laxative effect. It is unlikely that the military population can be exposed to high enough concentrations of these substances from ingestion of soil alone. Therefore, Soil-MEGs were not developed for these chemicals.

3.4.1.3 Essential Nutrients and Minerals

Some compounds have established recommended daily allowances (RDAs) because they are essential nutrients. The RDAs are not intended to be minimal

requirements nor necessarily optimal levels of intake; they are determined to be safe and adequate levels to ensure proper nutrition (NRC, 1989). Some nutrients do not have RDAs but have what are called "Safe and Adequate Intakes (SAI)". These levels are recommended for those nutrients that do not have sufficient data to derive an RDA but have known upper-level toxicity. Examples include the trace elements manganese, selenium and chromium. Other essential nutrients include minerals (e.g., zinc, calcium, magnesium). Generally, minerals are not chemicals of health concern. Although all chemicals are toxic at some level, these essential nutrients typically do not have recommended toxicity values (e.g. an RfD or an MRL) mostly because health effects are expected only at very high doses for the general population.

At this time, only a Soil-MEG for chromium has been developed since there is an available chronic RfD. Future Soil-MEGs may be derived using SAI for manganese and selenium. USACHPPM considered developing guidelines for calcium and magnesium using RDAs but, due to limited risk associated with these compounds in soil, the current guidance is to consider the presence of either of these compounds in soil as a no risk or "non-hazard".

3.4.2 Selection of Target Levels for Soil-MEGs

The intended application of soil guidelines is to monitor potential health risks from exposure to hazardous chemicals during deployment. For carcinogens, a target excess cancer risk level of 1×10^{-4} was used as the basis to develop the soil guidelines (see Section 3.1.5).

The potential for noncancer effects may be estimated by dividing a chemical's daily intake by its established toxicity value (e.g., RfD) to obtain a hazard quotient (HQ). The USEPA uses an HQ or target ratio of one for noncancer effects. Similarly, an HQ of one was used to develop MEGs based on noncancer effects. An exceedance of one does not imply immediate onset of health effects but rather, a potential for such. In addition, screening values are conservatively derived from toxicity data by utilizing uncertainty/safety factors to ensure protection. However, if an exceedance occurs, precaution should be taken to minimize further exposure. More discussion on the selection of toxicity data is presented in following sections.

Multiple chemicals may interact to result in additive, synergistic, or antagonistic responses. This is acknowledged in the TG as a potential area of concern. The guidance suggests comparing target organs of non-cancer compounds to ascertain whether (at a minimum) additive effects may be assumed. For carcinogens, there is also the assumption that two carcinogens are at least additive, regardless of type/target of carcinogenic action. This concept is consistent with current risk assessment/management approaches used by the USEPA. Recommendations in the TG are, however, to consider the carcinogenic WOE classification when determining potential strength of additive or synergistic cancer effects.

3.4.3 Method Selection

Several alternatives for estimating soil concentration are available: the USEPA's method for estimating Soil Screening Levels (SSL) (USEPA, 1996b), USEPA Region III's RBC, (USEPA, 1999d) and USEPA Region IX's Preliminary Remediation Goals (PRG) (USEPA, 1998). The theoretical approach is the same for all three, but the assumptions

vary. Region IX's method was used because it results in the most conservative soil concentrations since it includes more exposure pathways than either the SSL or the RBC methodology. The pathways include incidental soil ingestion, dermal contact, and inhalation of volatiles or fugitive dusts.

Region IX provides screening levels for both residential and industrial land uses; the major differences between the two are the exposure parameters such as inhalation rate and soil ingestion rate. Since the military personnel scenario is most similar to the industrial scenario, the equations for the industrial scenario were used. They are as follows:

Equation 3-11 – Soil-MEGs for Carcinogens

$$MEG_c = \frac{TR \times BW \times AT_c}{EF \times ED \times \left(\frac{IR_s \times FC \times CSF_o}{10^6} + \frac{SA \times AF \times ABS \times CSF_o}{10^6} + \frac{IR_a \times CSF_i}{PEF} \right)}$$

Equation 3-12 – Soil-MEGs for Noncarcinogens

$$MEG_{nc} = \frac{THQ \times BW \times AT_n}{ED \times EF \times \left(\frac{IR_s \times FC}{RfD_o \times 10^6} + \frac{SA \times AF \times ABS}{RfD_o \times 10^6} + \frac{IR_a}{RfD_i \times PEF *} \right)}$$

Where:

MEG_c	=	military soil guideline based on carcinogenicity (mg/kg)
MEG_{nc}	=	military soil guideline based on noncarcinogenicity (mg/kg)
TR	=	target risk
BW	=	adult body weight (kg)
AT_c	=	averaging time for carcinogenic substances (days)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
IR_s	=	soil ingestion rate
FC	=	fraction contaminated (assumed 100%)
CSF_o	=	oral cancer slope factor $(mg/kg/day)^{-1}$
10^6	=	units conversion (mg/kg)
SA	=	skin surface area (cm^2/day)
AF	=	adherence factor (mg/cm^2)
ABS	=	skin absorption
IR_a	=	air inhalation rate (m^3/day)
CSF_i	=	inhalation cancer slop factor $(mg/kg/day)^{-1}$
PEF	=	particulate emission factor *(or volatilization factor for volatiles)
THQ	=	target hazard quotient
RfD_o	=	oral reference dose (mg/kg/day)

3.4.3.1 Inhalation of Volatiles and Fugitive Dust in Surface Soils

Some chemicals can volatilize from the soil and be inhaled as vapor while others tend to adhere to soil particles that can then be inhaled as fugitive dust during such activities as foxhole digging. Whether or not a chemical will volatilize from the soil depends on the chemical's physicochemical characteristics. In the USEPA Region IX PRG equations, inhalation of volatile compounds is included by means of the soil-to-air volatilization factor (VF); the VF replaces the soil particulate emission factor (PEF) which is used for semi volatile organics and metals.

The same criteria used by USEPA Region IX were used to determine whether or not a chemical is volatile. They are based on chemical properties and depend on the two following conditions:

- Henry's Law constant ? to 10^{-5} atm-m^3/mole; and,
- Molecular weight < 200 g/mole.

When a chemical was identified as a VOC, its MEG was developed without the inhalation pathway because field sampling of air concentrations would capture these soil-to-air vapor concentrations. Therefore, military air guidelines (see Section 4) would be most applicable in addressing inhalation exposure for these chemicals.

Inhalation of nonvolatile in fugitive dust as a result of surface soil agitation was estimated using the PEF model. This factor is predominantly affected by wind erosion. The general PEF equation is shown in Equation 3-13:

Equation 3-13 – Particulate Emission Factor

$$PEF = \frac{Q}{C} \left[\frac{3600}{0.036 (1 - V) \left(\frac{U_m}{U_t} \right)^3 F(x)} \right]$$

Where:

PEF = particulate emission factor (m^3/kg)
3600 = units conversion (seconds per hour)
Q/C = simplified dispersion term, 90.80 (g/m^2-s per kg/m^3)
V = vegetative cover, 0.5 (50%)
U_m = mean annual wind speed, 4.69 m/s
U_t = equivalent wind speed threshold at 7 meters, 11.32 m/s
F(x) = function dependent on U_m/U_t, 0.194

USEPA recommended default values were used for all parameters. It should be noted, however, that these parameters are based on data obtained from the continental U.S. and may not be representative of other geographical regions. But without actual field data, these parameters cannot be accurately predicted.

For the dispersion term, which depends both on meteorological conditions and source size, the USEPA assumes a 0.5-acre square source area and uses the 90th

percentile Q/C as the default value when site-specific information is not available (USEPA 1996b). While the 0.5-acre square source area may not be the average size of a contaminated area during deployment, it is noted that only *decreases* in this value will result in more conservative MEGs and specifically will impact only those chemicals that are more toxic via inhalation). In most cases, increasing the source size did not impact final MEGs. It should be noted that using a source area of 0.5-acres to develop the MEGs does not mean that samples need to be obtained every 2 acres.

Applying the given parameters to Equation 3 results in a single PEF value of 1.32 x 10^9 m^3/kg. This value is applicable for all chemicals since the PEF is used to estimate the dust emission from the surface soil given various environmental conditions.

3.4.4 Soil Saturation Consideration

Certain factors such as a substance's physical chemical characteristics must be taken into account to ensure that the estimated soil concentrations are meaningful. For chemicals that were classified as volatiles using the criteria above, they were compared with a chemical-specific soil saturation concentration (C_{sat}) calculated using Equation 3-14:

Equation 3-14 – Soil Saturation Concentration

$$C_{sat} = \frac{S}{\rho_b}\left(K_d \theta_b + \theta_w + H' \theta_a\right)$$

Where:

C_{sat} = soil saturation concentration (mg/kg)
S = water solubility (mg/L water)
ρ_b = dry soil bulk density, 1.5 g/cm^3
θ_w = water-filled soil porosity, 0.15
H' = dimensionless Henry's Law constant
θ_a = air-filled soil porosity, 0.28
K_d = soil-water partition coefficient (L/kg)

As described by the USEPA Region IX guidance, the soil saturation limit determines the concentration at which the soil pore air and water volumes are saturated with the chemical. Above this level, the chemical may be a non-aqueous phase liquid (NAPL) if it is a liquid at ambient temperature, or a pure solid if it is a solid at ambient temperature. Therefore, it is not possible for the chemical to be present in the soil at a concentration higher than what the soil can physically hold. Subsequently, for liquid contamination, if a chemical's C_{sat} was lower than its health-based value, the C_{sat} was used as the final MEG.

Similarly, for inorganics and semi-volatiles, a maximum soil concentration is attained when the estimated soil concentration reaches 10^6 mg/kg. In the event where the estimated soil concentration exceeded this value of 10^6 mg/kg, the value itself was used as the MEG for that chemical.

3.4.5 Toxicity Data

3.4.6.1 Inhalation Toxicity

To be consistent with the air and drinking water guidelines, the hierarchies of toxicity values used to derive those guidelines were used to derive the soil guidelines. To estimate soil concentrations from chemicals that are carcinogenic via inhalation, CSF_is published by the USEPA in IRIS and HEAST were used. For the PAHs that have a USEPA WOE of B2, TEFs as recommended by the USEPA (USEPA, 1993) were applied to the CSF of benzo(a)pyrene as previously described in Section 4.3.

For non-carcinogenic effects, similar to the development of the PMEGs, subchronic RfCs were used followed by chronic RfCs and then by TLV?s. Since some TLVs? are based on a chemical's carcinogenicity, all TLV? s derived RfCs were checked with the background TLV? documentation to ensure that the TLVs? are based on noncarcinogenic effects. Currently, five chemicals within this document have TLV?-derived RfCs. These are: cadmium, chromium (III), chromium (VI), nickel, and xylene (mixture). Of the TLVs? used to derive the long-term MEGs, only that of cadmium is based on cancer (of the lungs). Upon closer evaluation, it was determined that the TLVs? of 0.002 mg/m^3 is for the respirable fraction. A different TLV? is available for the inhalable particulate fraction, which in this case, is more appropriate for the long-term MEGs because inhalation of metals from the soil is calculated using a particulate emission factor (see Equation 3-13). Therefore, the TLV? of 0.01 mg/m^3 as inhalable particulates was used to obtain a TLV?-derived RfC for cadmium. This TLV? is based on effects on the kidney.

Unlike the adjustment factors used for the PMEGs-L, the TLVs? were converted to RfCs as follows in Equation 3-15.

Equation 3-15 – Conversion of TLVs? to RfCs

$$RfC_{TLV} = TLV \times \left[\frac{5\ days}{7\ days} \times \frac{10\ m^3}{20\ m^3}\right] \times 0.1 \times \frac{TLV}{28}$$

As previously discussed, these adjustments are necessary to account for differences in exposure conditions. The higher inhalation rate of 29.2 m^3/day is omitted from this conversion because this factor is accounted for in Equation 3-2. Currently, no inhalation MRLs were used to derive the MEGs for the present list of chemicals.

3.4.6.2 Ingestion Toxicity

Oral CSFs from IRIS or HEAST were used for chemicals that are carcinogenic via ingestion. The TEFs from Table RD 3-2 were used to derive CSFs for carcinogenic PAHs. If a chemical was not carcinogenic, then an MEG based on carcinogenicity was not developed.

Oral reference doses (RfD_o) were used to estimate a chemical's MEG for noncancer effects. Although IRIS and HEAST provide RfD_os, these values were not used

because they are intended for longer-term exposures. Instead, the same rationale used to develop the MEGs was implemented. As a first step, the MEGs that are based on noncancer effects were used to back-calculate for an RfD_o as follows:

Equation 3-16 – Oral Reference Doses

$$RfD_o \left(\frac{mg}{kg/day}\right) = \frac{MEG \times 5\,L/day}{70\,kg}$$

If an MEG is based on a chemical's carcinogenicity, the hierarchy of toxicity data compiled during the development of the MEGs was assessed to determine the most appropriate noncancer toxicity value to use for that chemical. Based on this evaluation, it was determined that the MEGs of beryllium, ethylene dibromide and 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) could not be used to establish the RfD_os. Therefore, USEPA's longer-term HA was used as the RfD_o for beryllium and the ATSDR's MRL was used for RfD_o of 2,3,7,8-TCDD. Since no other noncarcinogenic data are available for ethylene dibromide, the MCL was used as the surrogate RfD_o for this compound. The same water ingestion rate and body weight factors as shown above, were used to convert these values to the appropriate units of mg/kg/day.

3.4.6.3 Dermal Toxicity

Currently, no dermal toxicity data is presented in either the USEPA's IRIS (USEPA, 1999a) database or HEAST database (USEPA, 1997a). These are the two most commonly used databases for oral and inhalation toxicity data for HRA purposes. The USEPA does, however, provide guidance on the use of surrogate information to develop dermal toxicity data when the need arises (USEPA 1989a). This involves using oral toxicity values and applying appropriate gastrointestinal (GI) absorption rates when they are available. If a chemical-specific GI ABS is not available, then a default value of 100 percent is recommended (i.e., dermal toxicity value is the same as the oral toxicity value). Using a 100 percent absorption may be less conservative in some instances. However, in light of the data gaps, this may be the best means to estimate dermal toxicity. For CSF the dermal toxicity value is obtained by dividing the oral CSF by the GI absorption rate. For non-cancer effects, the RfD_o is multiplied by the GI absorption rate to obtain a dermal RfD.

Not all chemicals are hazardous via dermal exposure. Therefore, information from the ACGIH was used to screen out substances that have no known dermal toxicity. Typically, when the ACGIH reports TLVs® for a substance, a chemical with a potential for dermal absorption is assigned a skin notation. This skin notation was used as a screening method for a chemical's potential to cause health effects from dermal exposure. Therefore, when a chemical is designated a skin notation, the dermal exposure pathway was included in Equations 3-11 and/or 3-12. For a chemical that is listed, but does not have a skin notation, the dermal exposure pathway was excluded. If a chemical is not listed by the ACGIH, the dermal exposure pathway was conservatively included to develop the MEG.

3.4.6.4 Derivation of a Soil-MEG for Pb

Pb has a USEPA WOE of B2 (probable human carcinogen based on evidence in animals and inadequate or no evidence in humans) and has known systemic toxicity

(refer to Section 4.8 for more discussion on lead toxicity). However, there are no recommended toxicity values to quantify lead exposure in soil. The USEPA recommends a soil-lead screening level of 400 ppm (mg/kg), which was derived using the Integrated Exposure Uptake Biokinetic Model (USEPA, 1994c,d), for residential exposures. This value is aimed at protecting the health of children who are more susceptible to lead poisoning. Since the military population does not include children, this soil-lead screening level would not be appropriate as the lead MEG.

Although USEPA Region IX recommends a soil screening level of 1000 ppm for industrial exposures, this value is based on USEPA default assumptions for industrial workers (e.g., soil ingestion rate of 50 mg/day). Since these assumptions are different from those used to derive the MEGs in this document, the 1000 ppm is not applicable as an MEG. In addition, it is unclear how 1000 ppm was derived using the Adult Lead Model (ALM) (TRW 1996). The Technical Review Workgroup (TRW) for lead suggests that a soil screening level of 750 ppm at industrial sites is a reasonable value (TRW 1999).

Using USEPA recommended lead exposure models is also problematic since these models generally use child-specific data. Therefore, the open literature was consulted for other models that can be used for adult lead exposure. During a telephone discussion with the USEPA's TRW for Lead, it was suggested that the Stern Model (Stern, 1996) might be more applicable for the purposes of the guidelines described in this document (Follansbee, 2000). The Stern Model is based on a relationship between blood pressure elevation and low-level lead exposure. During the last ten years, numerous studies have indicated a possible correlation between lead exposure and blood pressure, particularly in adult men (Harlan, 1988; Schwartz, 1995). However, as the ATSDR (ATSDR, 1999) points out, this relationship is still being debated in the scientific community. Other studies have shown weak or no correlation between blood pressure and blood lead (Elwood, 1988; Pocock, 1988). Since the relationship between blood pressure and low-level lead exposure is still a debatable issue, the Stern Model was not used.

A different model that does not depend on the blood lead-blood pressure relationship was also evaluated to establish a soil-lead concentration. The Bowers et al. (Bowers, 1994) model (herein referred to as the Bowers model) allows for the estimation of blood lead levels in adults exposed to environmental levels of lead. Since Bowers et al. considered blood-lead concentration from lead exposure to various media (primarily, soil, water, and air), for the purposes of the MEGs, the model was modified to exclude the other pathways. A comparison of the modified model with the ALM indicates that it is a component of the ALM.

A soil-lead concentration can be estimated using the Bowers model by back calculating from a target blood lead level. Equation 3-17 shows the modified relationship between soil-lead and blood lead concentration:

Equation 3-17 – Soil-Pb Concentration Estimate Using Stern Model

$$C_{lead} = \frac{PbB_2 - PbB_1}{BKSF \times AF_{s/d} \times IR_s}$$

Where:

MEG_{lead} = soil lead concentration (mg/kg)
PbB_1 = background blood lead concentration in adult male (µg/dL)
PbB_2 = target blood lead level (µg/dL)
BKSF = relationship between Pb soil ingestion and PbB (µg/dL)/(µg/day)
$AF_{s/d}$ = soil/dust absorption (unit less)
IR_s = soil ingestion rate (g/day)

Table RD 3-7 contains the parameters that were used to derive a MEG for lead. Those parameters recommended by the TRW for use in the ALM were used whenever possible.

Table RD 3-7. Input Parameters for the Modified Bowers Model

Parameter	Value	Rationale
PbB_2	30 µg/dL	See text for more discussion
PbB_1	2.0 µg/dL	Mid-range of 1.7 to 2.2 µg/dL as recommended by the TRW when demographic-specific information is not available
BKSF	0.4 µg/dL per µg/day	TRW's recommended default
$AF_{s/d}$	0.12	TRW's recommended default [based on absorption factor for soluble lead of 0.20 and a relative bioavailability of 0.6 (soil/soluble)]
IR_s	0.265 g/day	See Section 3.2.4

Various standards for lead exposure have been established to protect the health of workers. OSHA states that if a worker's blood lead exceeds 40 micrograms per deciliter (µg/dL), the worker must be temporarily removed for medical examinations (29 CFR). The OSHA also recommends that the blood lead of workers who intend to have children not exceed 30 µg/dL. This value is also the recommended ACGIH biological exposure index (BEI) for lead exposure in the workplace. In addition, almost all the studies reviewed by ATSDR (Table 2-1 of ATSDR 1999) show that no adverse health effects were observed in occupational populations where the blood-lead level was below 40 µg/dL. Therefore, 30 µg/dL was used as the target blood-lead level in Equation 3-17. Applying the parameters in Table RD 3-8 to Equation 3-12 results in a soil lead level of 2200 ppm.

3.4.6 Exposure Factors

Equations 3-11 and 3-12 require various exposure factors before soil concentrations can be calculated. Although USEPA Region IX provides default exposure factors for the residential and industrial scenarios, they may not all reflect the exposure factors typical of deployed situations. A discussion of each factor is presented in the following sections.

3.4.6.1 Exposure Duration and Frequency

As previously discussed (see Section 3.1) an ED of 1 year and EF of 365 days was assumed when deriving the guidelines in TG 230.

3.4.6.2 BW

As indicated in Section 3.1, a BW of 70 kg is used as the representative weight for deployed personnel.

3.4.6.3 Soil Ingestion

Currently, no information is available to estimate incidental soil ingestion for the military population either during training at continental U.S. facilities or during deployment. Although the USEPA provides adult-specific soil ingestion rates, the uncertainty associated with these recommendations is rather high because of the lack of adult-specific studies. Since soil ingestion is a function of age, studies have typically focused on children because of their behavioral patterns.

At present, the USEPA suggests a mean soil ingestion rate of 50 mg/day for adults (USEPA, 1997). However, an adult soil ingestion rate of 100 mg/day is still commonly used for residential or agricultural settings (USEPA, 1989a; USEPA, 1991a). For commercial and industrial scenarios, the soil ingestion rate is 50 mg/day (USEPA, 1991a). For certain activities such as construction or landscaping which involve a greater soil contact rate, a soil ingestion rate of 480 mg/day is recommended. This value is based on the assumption that the ingested soil comes from a 50 µm layer of soil adhered to the insides of the thumb and the fingers of one hand (USEPA, 1997c). All the ingestion rates presented above include ingestion of both soil and dust particles.

The activity of deployed military personnel is probably more similar to those of a construction worker than a resident. Activities may include digging or crawling on the ground leading to a higher soil exposure than the general U.S. population. However, the ingestion rate of 480 mg/day is not supported by measured data and thus contains a high degree of uncertainty (USEPA, 1997c). In addition, the USEPA advises that this value should only be used for short-term exposures (USEPA, 1991a). Despite this uncertainty, this value cannot be wholly discounted. Therefore, to estimate a soil ingestion rate for deployed scenarios, it was assumed that the deployed military personnel would be exposed at both the high ingestion rate and a mean ingestion rate throughout the year. The two ingestion rates were averaged to obtain a weighted daily ingestion rate as follows in Equation 3-18.

Equation 3-18 – Weighted Daily Soil Ingestion Rate

$$IR_{soil} = \frac{(480\ mg/day)*(182.5\ days) + (50\ mg/days)*(182.5\ days)}{365\ days} = 265\ mg/days$$

3.4.6.4 Inhalation Rate

As described in Section 3.2.4, a specific estimate of a deployed military person's inhalation rate was calculated assuming different activities rates throughout daily activities. This daily inhalation rate of 29.2 m^3/day was used to calculate the Soil-MEGs.

3.4.6.5 Dermal Exposure

Three parameters are needed to evaluate dermal uptake of chemicals from the soil. These include the skin surface area (SA) available for contact, the skin-to-surface adherence factor (AF) and the skin absorption factor (ABS). These parameters are either scenario-specific or chemical-specific. Although there are no known studies on soldier exposure to soil, the USEPA's *Exposure Factors Handbook* (USEPA, 1989b) provides sufficient data to estimate chemical uptake via the dermal route for deployment situations.

✍✍Skin Surface Area (SA) – The average amount of surface area available for contact depends on the type of clothing that is worn during deployment. While there may be instances where tops will be removed or sleeves will be rolled up during work, in general, military persons under deployment are expected to be clad in uniforms at all times. This ensures that they are camouflaged and protects them from injury or insect bites.

When a soldier is properly attired in the field, only the soldier's hands, head, and neck would be exposed. Also, to account for the likely instance of soldiers rolling up their sleeves, the SA from the forearm was also included to account for dermal exposure from soil. Using this assumption, the total exposed skin SA was derived from the USEPA's *Exposure Factors Handbook* (USEPA, 1997c) which contains SA for various body parts and for different percentiles. For the soil guidelines, the 90^{th} percentile SA of each exposed area of adult males was used since the USEPA believes that high end is conceptually above the 90^{th} percentile of a distribution (USEPA, 1992a). This ensures that the soil guidelines would be protective of the high end individuals. Therefore, a final SA of 4090 cm^2 was used to derive the soil guidelines for deployed situations. This number is based on SAs of 0.112 m^2, 0.140 m^2, and 0.157 m^2 for the hands, head, and forearms, respectively.

✍✍Skin-To-Surface AF – The AF is primarily dependent on soil property, the part of the body that is exposed, and the type of activity. Since little is known about the extent of soil adherence to the skin for military-specific activities, AFs developed from other activities were reviewed as a possible source of surrogate data. Various activity factors of deployment scenarios must be considered to select a representative AF.

Based on activity pattern, it can be concluded that a deployed personnel's activities most resemble those of outdoor workers such as farmers. This group of people tends to have a high soil contact rate. However, the AFs presented in the USEPA's *Exposure Factors Handbook* do not appear to fit those of deployed personnel. Part of this is due to the difference in the body coverage by clothing. Since outdoor work tends to be performed during warmer months, subjects from the studies used in the *Exposure Factors Handbook* have more exposed SA for soil contact. Other factors to consider include the fact that a deployed personnel may not have the opportunity to shower daily. Therefore, the amount of soil that adheres to the skin can accumulate in between washing. In addition, for high intensity tasks, more soil can stick to the skin because of sweating (USEPA, 1989b).

Based on the lack of information, a default upper tendency value of 1.0 mg/cm^2 per event (USEPA, 1992b) was used for the deployment scenario. Selection of a higher AF can also account for some of the soil and dust particles getting beneath the clothing layer. This parameter may be adjusted in the future as more representative AFs become available.

✍✍Skin Absorption Factor (ABS) – The ABS is a chemical-specific parameter used to estimate the amount of chemical that travels across the skin barrier. This parameter is used in conjunction with the AF discussed above. The AF determines how much soil is available for contact while the ABS determines how much of the chemical bound to the soil particle actually gets absorbed dermally.

Very few chemical-specific ABS have been developed. The USEPA lists only about 10 chemicals with suggested chemical-specific ABS values, all of which are less than 10 percent. For chemicals with no ABS, USEPA Region IX suggests using default values of 1 percent for inorganics and 10 percent for organics, respectively. This is similar to Region III's recommended defaults of 1 percent for metals, 3 percent for volatiles, and 10 percent for semi volatiles and pesticides. Using these same recommendations, values of 1 percent and 10 percent for inorganics and organics were used to develop MEGs when chemical-specific data were not available.

Chemical-specific ABS values have been proposed for some of the chemical warfare agents (Major, 1998). These ABS values are based on an hourly soil absorption rate. To account for the situation where military personnel under deployment may not shower everyday, thereby, prolonging the adherence of contaminated soil to the skin, a 24-hour exposure was assumed to develop the MEGs. Since no chemical-specific ABS has been developed for lewisite, the USEPA's default of 10 percent for organics was used for lewisite.

Table RD 3-8. Skin Absorption Factors Used for the Development of Soil-MEGs

Chemical	ABS
Inorganics	1% per day
Organics	10% per day
GA	0.35% per hour
GB	0.26 % per hour
GD	0.78% per hour
HD	0.70% per hour
VX	0.27% per hour

3.4.7 Consideration of Acute Toxicity

It is often assumed that when using sub-chronic or chronic toxicity criteria as the underlying basis for a risk assessment, that the resulting health-based levels (e.g. the MEGs) will be protective against all adverse health effects, including immediate or acute effects associated with single or short-term exposures. Since the specific scenario used to calculate MEGs assumes much shorter duration of exposure than that typically used in USEPA risk assessment, it was necessary to evaluate whether the resulting guidelines could pose immediate/acute health effects after short-term exposures. To ensure that the MEGs do not exceed acutely toxic levels, they were compared with USEPA's short-term one-day drinking water Health Advisories (HA) (USEPA, 1996a).

As noted in TG 230, these HAs are protective for up to 5 days of consecutive exposure. Henceforth, they are referred to as 5-day HAs for the purpose of this document.

To compare the MEGs and the 5-day drinking water HAs, all concentrations were converted to an intake or a dose (i.e., mg/kg/day). Therefore, the HAs were adjusted by the amount of water typically consumed in the field (5 L) and the average adult BW as follows:

Equation 3-19 – Equivalent Acute RfDs

$$RfD_{acute} = \frac{HA_{5days} \times IR_w}{BW}$$

Where:

RfD_{acute} = equivalent acute reference dose (mg/kg/day)
$HA_{5\ days}$ = 5-day health advisory (mg/L)
IR_w = water ingestion rate, 5L/day
BW = average body weight, 70 kg

Similarly, the MEGs were converted from a soil concentration to an intake as follows:

Equation 3-20 – Daily Intake from Soil

$$I_{soil} = \frac{MSG \times FC \times IR_s}{BW \times 10^{6}}$$

Where:

I_{soil} = daily intake of chemical from soil (mg/kg/day)
MEG = military soil guideline, long-term (mg/kg)
FC = fraction of soil contaminated, 100% (unit less)
IR_s = soil ingestion rate, 265 mg/day
BW = body weight, 70 kg
10^6 = conversion from mg to kg

While the objective here was to ensure that the MEGs do not exceed acute health concerns, it should be noted that unique 'short-term exposure scenarios' (such as where the ingestion rate might be exceedingly higher than the average rates assumed in MEG calculations) were not specifically evaluated.

As noted in Equation 3-20, only the ingestion route of exposure was used to estimate an intake using the MEG. This is mainly because the HAs are intended for ingestion only and currently, little information is available to evaluate health effects from dermal contact for acute exposures. In addition, the soil ingestion pathway generally dominates as the major pathway of concern when compared with the inhalation of fugitive dust.

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APPENDIX A
REFERENCES

APPENDIX A - References

REFERENCES

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APPENDIX B
ACRONYMS

APPENDIX B - Acronyms

ABS	Skin Absorption Factor
ACGIH	American Conference of Governmental Industrial Hygienists
Adj	Adjusted
AEGL	Acute Exposure Guideline Level
AF	Adherence Factor
AIHA	American Industrial Hygiene Association
ALM	Adult Lead Model
AMEDD	Army Medical Department
ANOVA	Analyses of Variance
AQI	Air Quality Index
AT	Averaging Time
ATSDR	Agency for Toxic Substances and Disease Registry
AUR	Air Unit Risk
BEI	Biological Exposure Index
BW	Body Weight
CAS	Chemical Abstract Service
CAWG	Chemical Agent Working Group
CEGLs	Continuous Exposure Guidance Levels
CFR	Code of Federal Regulation
cm^2	square centimeter
CN	Cyanide
CN/L	Cyanide/ L
CNS	Central Nervous System

CO	Carbon Monoxide
CONUS	Continental United States
COT	Committee on Toxicology
cPAHs	Carcinogen Polycyclic Aromatic Hydrocarbons
C_{sat}	Soil Saturation Concentration
CSF	Cancer Slope Factor
CSFi	Inhalation Cancer Slope Factor
CSFo	Oral Carcer Slope Factor
CWA	Chemical Warfare Agents
CVS	Cardiovascular System
DIMP	Diisopropyl methylphosphate
DNBI	Disease and Non-Battle Injury
DOD	Department of Defense
DODI	Department of Defense Instruction
DOE	Department of Energy
DODI	Department of Defense Instruction
ED	Exposure Duration
EEGLs	Emergency Exposure Guidance Levels
EF	Exposure Frequency
ERPG	Emergency Response Planning Guideline
FDWS	Field Drinking Water Standards
FHP	Force Health Protection
FM	Field Manual
gm	Gram
g/kg	Gram per kilogram

GI	Gastrointestinal
gm/L	Gram per Liter
HAs	Health Advisories
HAs-Adj	Health Advisories-Adjusted
HC	Hexachloroethane
HEAST	Health Effects Assessment Summary Tables
HEC	Human Equivalency Concentration
HRA	Health Risk Assessment
HSDB	Hazardous Substance Databank
HQ	Hazard Quotient
IC_{50}	Incapacitating Concentration for 50 percent exposed population
IDLH	Immediately Dangerous to Life and Health
IMP	Isopropyl methylphosphonate
IR	Inhalation Rate
IRIS	Integrated Risk Information System
ITF	International Task Force
Kg	kilogram
L	Liter
LC_{50}	Lethal Concentration for 50 percent of the exposed population
LC_{LO}	Lowest Lethal Concentration
LD	Lethal Dose
LD_{50}	Lethal Dose 50%
L/day	Liter per day
LOAEL	Lowest Observed Adverse Effects Level
MAF	Military Adjustment Factor

MEG	Military Exposure Guideline
MCLGs	Maximum Contaminant Level Goals
MCL	Maximum Contaminant Level
MCRC	Military Cancer Risk Concentration
MRC	Military Risk Concentration
MRLs	Minimal Risk Levels
m	meter
m^3/day	cubic meter per day
m^3/hr	cubic meter per hour
?**g/dl**	microgram per deciliter
?**g/kg/day**	Microgram per kilogram per day
?**g/kg**	microgram per kilogram
?**g/L**	microgram per liter
?**g/m^3**	microgram per cubic meter
mg/cm^2	milligram per square centimeter
mg/day	milligram per day
mg/kg	milligram per kilogram
mg/kg/day	milligram per kilogram per day
mg/L	milligram per Liter
mg/m^3	milligram per cubic meter
MOPP	Mission-Oriented Protective Posture
NA	Not applicable
NAAQS	National Ambient Air Quality Standards
NAC	National Advisory Committee
NAPL	Non-aqueous phase liquid

NAS	National Academy of Science
NATO	North Atlantic Treaty Organization
NBC	Nuclear, Biological, and Chemical
NBC-E	Nuclear, Biological, and Chemical Environment
NCHS	National Center for Health Statistics
ND	Not determined
NIOSH	National Institute of Safety and Occupational Health
NO_2	Nitrogen Dioxide
NO_x	Oxides of Nitrogen
NOAEL	No-Observed Adverse Effect Level
NRC	National Research Council
O_3	Ozone
OCONUS	Outside the continental United States
ORD	Office of Research and Development
ORM	Operational Risk Management
OSHA	Occupational Safety and Health Administration
PAHs	Polycyclic Aromatic Hydrocarbons
Pb	Lead
PBPK	Physiologically-Based Pharmacokinetic Model
PEF	Particulate Emission Factor
PEGL	Permissible Exposure Guidelines Level
PEL	Permissible Exposure Limit
PM	Particulate Matter
PMEGs	Preliminary Military Air Guidelines
Ppm	parts per million

PRG	Preliminary Remediation Goals
PSI	Pollution Standard Index
QSTAG	Quadripartite Standardization Agreement
RBC	Risk Based Concentration
RD	Reference Document
RDA	Recommended Daily Allowance
RfC	Reference Concentration
RfD	Reference Dose
RfD-Adj	Adjusted Chronic/ Sub-chronic Reference Dose
RfD_i	Inhalation Reference Dose
RfD_o	Oral Reference Dose
ROWPU	Reverse Osmosis Water Purification Unit
SA	Surface Area
SAI	Safe and Adequate Intake
SCAPA	Subcommittee on Consequence Assessment and Protective Actions
SO^2	Sulfur Dioxide
SOH	Safety and Occupational Health
SPEGLs	Short-term Public Guidance Levels
SSL	Soil Screening Level
SST	Soil Screening Level
STANAG	Standardization Agreement
STEL	Short-term Exposure Level
TB MED	Technical Bulletin, Medical
TCR	Target Cancer Risk
TEELs	Temporary Emergency Exposure Limits

TEFs	Toxic Equivalent Factors
TG	Technical Guide
THQ	Target Hazard Quotient
TICs	Toxic Industrial Chemicals
TIMs	Toxic Industrial Materials
TLVs®	Threshold Limit Values
TLVs®-Adj	Threshold Limit Values-Adjusted
TPH	Total Petroleum Hydrocarbons
TRI	Toxic Release Inventory
TRW	Technical Review Workgroup
TT	Treatment Technique
TWA	Time-Weighted Average
UF	Uncertainty Factor
USACHPPM	U.S. Army Center for Health Promotion and Preventive Medicine
USARIEM	U.S. Army Research Institute of Environmental Medicine
USEPA	U.S. Environmental Protection Agency
VF	Volatilization Factor
VOC	Volatile Organic Compounds
WOE	Weight-of-Evidence
WQAS-PM	Water Quality Analysis Set-Preventive Medicine
$ZnCl_2$	Zinc Chloride

APPENDIX C
DERIVATION OF MILITARY EXPOSURE GUIDELINES FOR AIR

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Table C-1: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
Acetone cyanohydrin 75-86-5	16.4[C] [4.7]	ND	ND	Dermal exposures can contribute to systemic dose. Ceiling value derived as CN.	Only acute value available.
Acrolein 107-02-8	0.07 [0.03] (AEGL-1*)	0.23 [0.1] (AEGL-2*)	3.2 [1.4] (AEGL-3*)	Concentrations of 0.06 ppm for 5 min caused irritation in humans.	*Proposed AEGL's published in Fed. Reg. ERPG (1-3): 0.1, 0.5, 3 ppm; EEGL – 0.05 ppm; Ceiling value – 0.1 ppm, IDLH – 2 ppm.
Acrylonitrile 107-13-1	22 [10] (ERPG-1)	76 [35] (ERPG-2)	163 [75] (ERPG-3)	Lethality was observed in dogs after exposure to 65 ppm for 4 hrs.	IDLH – 85 ppm.
Aldrin 309-00-2	ND	ND	25 (IDLH)	Based on oral data; 18 mg/m^3/day caused no effects in man; ingestion of 25.6 mg/kg caused convulsions in 20 min (extrapolated: 1200 mg/m^3 for 30 min) (NIOSH 1994).	No other acute values available.
Allyl alcohol 107-18-6	4.4 [1.8] (AEGL-1*)	18.3 [7.7] (AEGL-2*)	48 [20] (AEGL-3*)	NIOSH (1994) notes that inferences from animal experiments suggest that single 1-hour exposures of 150 ppm may be fatal, yet exposures to 100 ppm would probably allow survival.	*Proposed AEGL's published in Fed. Reg. TEEL (1-3): 4, 15, 20 ppm; STEL - 4 ppm; IDLH - 20 ppm.
Ammonia 7664-41-7	17 [25] (AEGL-1*)	77 [110] (AEGL-2*)	766 [1100] (AEGL-3*)	Minimal effect levels based on eye and respiratory irritation; significant to severe irritation in subjects exposed to 500 ppm for 0.5 hrs (NIOSH 1994).	*Proposed AEGL's published in Fed. Reg. ERPG (1-3): 25, 150, 750 ppm; STEL - 35 ppm; EEGL – 100 ppm; IDLH – 300 ppm.
Arsine 7784-42-1	NA	0.54 [0.17] (AEGL-2)	1.6 [0.5] (AEGL-3)	Levels based on methemoglobin synthesis and hemolysis (and subsequent renal effects); NIOSH (1994) states that 6 – 30 ppm is maximum concentration for 1 hr without serious consequences.	ERPG (1-3): NA, 0.5, 1.5 ppm; EEGL – 1 ppm; IDLH – 3 ppm.

* Notes for table on page C-1-17

Table C-1: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
Benzene 71-43-2	160 [50] (ERPG-1)	479 [150] (ERPG-2)	3195 [1000] (ERPG-3)	Exposure at 1500 ppm for 1 hr induces serious symptoms; exposure at 500 ppm for 1 hr leads to symptoms of illness; exposure at 150 ppm for 5 hrs produces headache, lassitude, and weakness (NIOSH 1994).	STEL - 2.5 ppm; EEGL – 50 ppm; IDLH – 500 ppm.
Boron tribromide 10294-33-4	10 [1^C]	ND	ND	Considered primary irritant (see Appendix D). Minimal effect levels based on NOAEL in rats; rats exposed for 6 hrs/day, 5 days/wk for 3 months produced transient signs of irritation; rounded up to be consistent with the 1-14 day value.	Ceiling value – 10 mg/m^3.
Boron trifluoride 7637-07-2	2 [0.73] (ERPG-1)	30 [11] (ERPG-2)	100 [36] (ERPG-3)	Considered primary irritant (see Appendix D).	ACGIH ceiling value – 3 mg/m^3. No other acute values available.
Bromine 7726-95-6	0.16 [0.024] (AEGL-1*)	1.6 [0.24] (AEGL-2*)	56 [8.5] (AEGL-3*)	Concentrations above 10 ppm cause severe upper respiratory irritation; 1.7 – 3.5 ppm produces severe choking; 30 ppm would be fatal in a short duration (NIOSH 1994).	*Proposed AEGL's published in Fed. Reg. ERPG (1-3): 0.2, 1, 5 ppm; STEL - 0.2 ppm; IDLH – 3 ppm.
Butyl isocyanate (n-) 111-36-4	0.04 [0.01] (ERPG-1)	0.2 [0.05] (ERPG-2)	4.1 [1] (ERPG-3)	A 4-hr LC_{01} for rats was 6.8 ppm. Concentrations of 0.1 – 1 ppm produce irritation to the respiratory tract and mucous membranes (AIHA 1999).	No other acute values available.
Carbon disulfide 75-15-0	3 [1] (ERPG-1)	156 [50] (ERPG-2)	1557 [500] (ERPG-3)	Exposures to 4800 ppm for 30 min cause coma and is fatal; severe symptoms and unconsciousness may occur within 30 min at 1100 ppm; 760 ppm causes an immediate headache that lasts for hrs (NIOSH 1994).	EEGL – 50 ppm; IDLH – 500 ppm.

Table C-1: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
Carbon monoxide 630-08-0	229 [200] (ERPG-1)	286 [350] (ERPG-2)	572 [500] (ERPG-3)	1-hr exposures to 1000 – 1200 ppm will cause unpleasant but no dangerous symptoms; 1500 – 2000 may be dangerous after 1 hr.	IDLH – 1200 ppm; EEGL – 400 ppm.
Carbon tetrachloride 56-23-5	75 [12] (AEGL-1*)	428 [68] (AEGL-2*)	1070 [170] (AEGL-3*)	Exposures to 1000 – 2000 ppm for 0.5 – 1.0 hrs have caused human fatalities and kidney damage; 30-min exposure to 300 ppm causes symptoms of intoxication (NIOSH 94).	*Proposed AEGL's published in Fed. Reg. ERPG (1-3): 20, 100, 750 ppm; Above odor threshold; STEL – 10 ppm; IDLH – 200 ppm.
Chlorine 7782-50-5	2.9 [1] (AEGL-1)	5.8 [2] (AEGL-2)	64 [22] (AEGL-3)	Exposures of 30 min cause intense coughing fits; a concentration of 34 – 51 ppm has been reported to be fatal in 1 – 1.5 hrs.	ERPG (1-3): 1, 3, 20 ppm; STEL – 1 ppm; EEGL – 3 ppm; IDLH – 10 ppm
Chlorine trifluoride 7790-91-2	1.3 [0.35] (AEGL-1*)	11.7 [3.1] (AEGL-2*)	53 [14] (AEGL-3*)	Exposures of 50 ppm for 0.5 – 2 hrs may be fatal.	*Proposed AEGL's published in Fed. Reg. ERPG (1-3): 0.1, 1, 10 ppm; EEGL – 1 ppm; Ceiling value – 0.1 ppm; IDLH – 20 ppm.
Chloroacetaldehyde 107-20-0	3.2 [1^C]	71 [22] (TEEL-2)	144 [45] (TEEL-3)	Volunteers found that concentrations of 45 ppm were very disagreeable, and conjuctival irritation was noted (NIOSH 1994).	IDLH – 45 ppm.
Chloroacetone 78-95-5	3.8 [1^C]	ND	ND	Concentration of 605 ppm is lethal after a 10-min exposure and 26 ppm is intolerable after a 1-min exposure (ACGIH 1991).	No other acute values available.
Chloroacetophenone [CN] 532-27-4	ND	ND	15 IDLH	Concentration of 31 mg/m^3 is intolerable after 3 min (NIOSH 1994).	IDLH – 15 mg/m^3.
Chloroacetyl chloride 79-04-9	0.23 [0.05] (ERPG-1)	2.3 [0.5] (ERPG-2)	46 [10] (ERPG-3)	Exposures exceeding 0.14 ppm may cause slight eye irritation and respiratory irritation.	STEL – 0.15 ppm.

Table C-1: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
Chlorobenzylidene malonitrile o- [CS] 2698-41-1	0.39 [0.05^C]	ND	2 [0.26] (IDLH)	Incapacitating concentration range from 12 – 20 mg/m^3 after 20 seconds of exposure (NIOSH 1994).	No other acute values available.
Chloroform 67-66-3	NA	430 [88] (AEGL-2*)	3174 [650] (AEGL-3*)	Disorientation occurs at concentrations exceeding 1000 ppm (NIOSH 1994).	*Proposed AEGL's published in Fed. Reg. ERPG (1-3): NA, 50, 5000 ppm; REL 1 – 0.74 ppm; EEGL – 1000 ppm; IDLH 500 ppm.
Crotonaldehyde 4170-30-3	0.54 [0.19] (AEGL-1)	12.6 [4.4] (AEGL-2)	40 [14] (AEGL-3)	Exposure to 4.1 ppm for 15 min was reported to be highly irritating to the nose and upper respiratory tract (NIOSH 1994).	ERPG (1-3): 2, 10, 50 ppm; IDLH – 50 ppm.
Cyanogen 460-19-5	22 [20] (*)	78 [71] (*)	166 [150] (*)	*Based on 10 x Hydrogen Cyanide AEGLs according to ACGIH Documentation of the Threshold Limit Values and Biological Exposure Indices. 6th ed. Volumes I,II, III. Cincinnati, OH: ACGIH, 1991 cyanogen is "10 times less acutely toxic).	64 [30] TEEL-1); 107[50](TEEL-2); 107 [50](TEEL-3);
Diborane 19287-45-7	0.34 [0.3] (TEEL-1)	1.13 [1] (AEGL-2)	4.2 [3.7] (AEGL-3)	Dogs experienced minor irritation at 1 ppm for 1 hr (AIHA 1999). AIHA determined odor threshold insufficient to derive a minimal effect levels.	ERPG (2-3): 1, 3 ppm, IDLH – 15 ppm.
Dichloroethane (1,1-) 75-34-3	ND	ND	12,144 [3000] (IDLH)	Rats survived 4-hr exposures of 4000 ppm but not 16000 ppm; may cause narcosis at lower concentrations (NIOSH 1994).	No other acute values available.
Dieldrin 75-34-3	0.75 (TEEL-1)	1.25 (TEEL-2)	50 (IDLH)	Lethal oral dose = 5 g (equivalent to 3300 mg/m^3 for 30 min); (NIOSH 1994).	No other acute values available.

Table C-1: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
Diesel fuel smoke	8 (SPEGL)	80 (EEGL)	ND	No irritant effects in humans; pulmonary inflammation in rats (NRC[a]).	No other acute values available.
Diketene 674-82-8	3.4 [1] (ERPG 1)	17 [5] (ERPG 2)	69 [20] (ERPG 3)	Serious signs of toxicity observed in rats at 250 ppm surviving a 1-hr exposure (AIHA 1999).	No other acute values available.
Dimethyl sulfate 77-78-1	1.5 [0.3] (TEEL-1)	5.2 [1] (TEEL-2)	36 [7] (IDLH)	20-min exposures to 13 ppm caused severe symptoms in monkeys; death (LC_{50}) in guinea pigs at 75 ppm (NIOSH 1994).	No other acute values available.
Endrin 72-20-8	0.1^S [0.008] TWA 8-hr	0.3 [0.024] **	2.0 (IDLH, TEEL 2)	Oral dose of 171 mg/kg is lethal; 0.2 mg/kg may cause convulsions (equivalent to 8000 ppm and 9 ppm, respectively); (NIOSH 1994).	**TEEL-1 = 0.3; **ACGIH 3 x Excursion Limit -0.3 mg/m³ TEEL 2 = 2.0
Ethyl benzene 100-41-4	542 [125] (TEEL-1)	4342 [1000]	8684 [2000]	Dizziness may occur after 5 min of exposure to 2000 ppm (NIOSH 1994). IDLH based on 1/10th lower explosive limit.	STEL – 125 ppm; Significant (strong eye irritation/tear/with tolerance developing) and Severe (intolerable eye irritation and lacrimation) levels based on Grant, W.M, "Tox of the Eye, 1986, peer reviewed; 542 [125] =TEEL-2; IDLH = 800 ppm
Ethylenimine 151-56-4	2.64 [1.5] (TEEL-1)	8.1 [4.6] (AEGL-2*)	17.4 [9.9] (AEGL-3*)	Powerful lacrimator and emetic; exposures exceeding 100 ppm have caused respirator irritation and inflammation, yet symptoms may be delayed several hours (NIOSH 1994).	*Proposed AEGL's published in Fed. Reg. TEEL (1-2): 1.5, 2.3 ppm, IDHL- 100 ppm.
Ethylene oxide 75-21-8	14 [7.5] (TEEL-1)	81 [45] (AEGL-2)	360 [200] (AEGL-3)	Exposures above 2000 ppm have caused headache, nausea, vomiting, dyspnea, and respiratory irritation; concentrations > 1 hr at 2000 ppm may be fatal (NIOSH 1994). AIHA determined insufficient data to	ERPG (2-3): 50, 500 ppm; IDLH – 800 ppm.

Table C-1: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
				derive a minimal effect level.	
Fluorine 7782-41-4	3.1 [2] (AEGL-1)	7.8 [5] (AEGL-2)	20.2 [13] (AEGL-3)	Concentrations of 25 ppm have been tolerated briefly, yet both volunteers developed sore throats and chest pains that lasted 6 hrs; 50 ppm could not be tolerated (NIOSH 1994). Minimal effect levels based on objectionable odor threshold, yet repeated exposures to workers of 10 ppm has been reported to be well tolerated (AIHA 1999).	ERPG (1-3): 0.5, 5, 20 ppm; EEGL – 7.5 ppm; STEL – 2 ppm; IDLH – 25 ppm; ERPG-1 – 0.5 ppm.
Fog oil smoke	9 (SPEGL)	90 (EEGL)	ND	Based on Shoshkes, et al. (1950). Haber's law applied based on the similarity of fog-oil and diesel-fuel smokes (in NRC[a]).	No other acute values available.

Table C-1: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
Formaldehyde 50-00-0	1.2 [1] (ERPG-1)	12.3 [10] (ERPG-2)	31 [25] (ERPG-3)	5 to 10 min exposures to 50 – 100 ppm may cause serious injury to the lower respiratory tract; many volunteers could not tolerate prolonged exposures to 4 - 5 ppm (NIOSH 1994).	ACGIH ceiling – 0.3 ppm; IDLH – 20 ppm.
GA (Tabun) 77-81-6	0.00042 (0.0028) (AEGL-1)	0.0053 (0.035) (AEGL-2)	0.039 (0.26) (AEGL-3)	Based on relative potency from GB (see text for more information); (EPA 2001).	Existing (Recommended) IDLH = 0.2 (0.1) mg/m3
GB (Sarin) 107-44-8	0.00048 (0.0028) (AEGL-1)	0.0060 (0.035) (AEGL-2)	0.022 (0.13) (AEGL-3)	Level-1: Reversible miosis, headache, eye pain, rhinorrhea, tightness in chest, cramps, nausea, malaise, miosis in human volunteers; may limit performance for night operations, aircrews, and tasks involving distance or spatial judgement Level-2: Reversible miosis, dyspnea, RBC-ChE inhibition, single fibre electromyography (SFEMG) changes in human volunteers; may limit performance for night operations, aircrews, and tasks involving distance or spatial judgement Level-3: Based on GB vapor experimental Sprague-Dawley rat lethality data (LC_{01}, LC_{50}) (see text for more information); (EPA 2001).	Existing (Recommended) IDLH = 0.2 (0.1) mg/m^3

Table C-1: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
GD (Soman) 96-64-0	0.00018 (0.0014) (AEGL-1)	0.0022 (0.018) (AEGL-2)	0.017 (0.13) (AEGL-3)	Based on relative potency from GB (see text for more information); (EPA 2001).	Existing (Recommended) IDLH = 0.06 (0.05) mg/m^3
GF 329-99-7	0.00020 (0.0014) (AEGL-1)	0.0024 (0.018) (AEGL-2)	0.018 (0.13) (AEGL-3)	Based on relative potency from GB (see text for more information); (EPA 2001).	(Recommended) IDLH = (0.05) mg/m^3 (no previous existing estimate)
Hexachlorobutadiene 87-68-3	32 [3] (ERPG-1)	107 [10] (ERPG-2)	320 [30] (ERPG-3)	Less than odor threshold; concentrations of 23 ppm (245 mg/m^3) produced strong odors; 1 ppm (10 mg/m^3), faint.	No other acute values available.
Hexachlorocyclo-pentadiene 77-47-4	0.1 [0.01] 8-hr TLVs? –	0.35 [0.03] ACGIH excur limt – 3xTWA	1.6 [0.15] (*)	Rabbit lethality at 1.5 PPM (15.9 mg/m^3) for 7 hr; mice- 1.4 ppm (15.2 mg/m^3) for three 7-hr periods; rats- 1.0 ppm (10.9 mg/cu m) for five 7-hr periods or 3.2 ppm (35.1 mg/m^3) for two 7-hr periods; American Conference of Governmental Industrial Hygienists. Documentation of the Threshold Limit Values and Biological Exposure Indices. 5th ed. Cincinnati, OH:American Conference of Governmental Industrial Hygienists, 1986. 300]**PEER REVIEWED**	Rabbit lethality at 1.5 PPM (15.9 mg/m^3) for 7 hr was divided by an uncertainty factors (animal to human) of 10. This and the additional conservatism of usng a 7-hr exposure is considered to be a reason crude Severe effects/thrshold fatality estimate. Significant is based on ACGIH "Excursion Limit" which is 3 times the TWA TEEL 1 – 3 values identical 0.22 [0.02] based on limited data;
Hexachloroethane smoke 67-72-1	0.3 (SPEGL)	3 (EEGL)	ND	Based on reports from acute human inhalation exposures (NRC[a]).	IDLH – 300 ppm (based on oral toxicity); deemed not appropriate for use.
Hexane 110-54-3	528 [150] (TEEL-1)	880 [250] (TEEL-2)	3872 [1100] (TEEL-3)	Exposures of 10 min to 5000 ppm caused dizziness and a feeling of giddiness (NIOSH 1994).	IDLH – 1100 ppm; STEL – 1000 ppm.

Table C-1: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
Hydrazine 302-01-2	0.13 [0.1] (AEGL-1)	17 [13] (AEGL-2)	46 [35] (AEGL-3)	Exposures of 4 hr to 80 – 300 ppm was lethal to rats (NIOSH 1994).	TEEL (1-3): 0.3, 0.8, 10 ppm; IDLH – 50 ppm; SPEGL – 0.12 ppm.
Hydrogen bromide 10035-10-6	9.9 [3] (TEEL-1) (ACGIH Ceiling)	19.8 [6] (*)	99 [30] (TEEL-3)	Exposures of 1300 – 2000 ppm may be lethal in exposures lasting a few minutes; 2 – 6 ppm has been reported to cause nose and throat irritation (NIOSH 1994).	IDLH – 30 ppm; ACGIH Ceiling – 3 ppm. 9.9 [3] =TEEL-2 *For Significant Level – use “6” ppm, based on ACGIH – ref. Clayton; G.D., Pattys IH and Tox; Vol 2, 1994; significant eye and nasal irritation
Hydrogen chloride 1333-74-0	2.7 [1.8] (AEGL-1)	33 [22] (AEGL-2)	155 [104] (AEGL-3)	Concentrations of 35 ppm caused throat irritation; 50 – 100 ppm are barely tolerable (NIOSH 1994). Concentrations exceeding 3 ppm may produce discomfort in asthmatics.	ERPG (1-3): 3, 20, 150 ppm; IDLH - 50 ppm; ACGIH Ceiling – 5 ppm; EEGL – 20 ppm.
Hydrogen cyanide 74-90-8	2.2 [2] (AEGL-1)	7.8 [7.1] (AEGL-2)	16.6 [15] (AEGL-3)	Concentrations of 45 – 54 ppm may be tolerable for 0.5 – 1.0 hr; 110 – 135 ppm may be fatal after 0.5 – 1.0 hr or later (NIOSH 1994).	TEEL 1 - 4.7; ERPG (2-3): 10, 25 ppm; IDLH – 50 ppm; ACGIH Ceiling – 4.7 ppm.
Hydrogen fluoride 7664-39-3	0.82 [1] (AEGL-1)	19.6 [23] (AEGL-2)	36 [44] (AEGL-3)	Concentrations of 50 ppm for 30 – 60 min may be fatal; volunteers tolerated 4.7 ppm for 6 hrs/day for 10 – 50 days (NIOSH 1994).	ERPG (1-3): 2, 20, 50 ppm; IDLH – 30 ppm; ACGIH Ceiling – 3 ppm; EEL – 8 ppm; ERPG-1 – 0.1 ppm.
Hydrogen selenide 7783-07-5	ND	ND	3.3 [1] (IDLH)	IDLH based on Se; human data used.	No other acute values available.
Hydrogen sulfide 7783-06-4	0.23 [0.17] (AEGL-1)	39 [28] (AEGL-2)	70 [50] (AEGL-3)	Concentrations of 170 to 300 ppm are the maximum tolerated concentrations for 1-hr without serious consequences; olfactory fatigue occurs at 100 ppm (NIOSH 1994). Minimal effect levels based on objectionable odor at 0.3 ppm.	ERPG (1-3): 0.1, 30, 100 ppm; IDLH – 100 ppm; STEL – 15 ppm, EEGL (10 min) – 50 ppm; ERPG-1 – 0.1 ppm.

Table C-1: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
Iron pentacarbonyl 13463-40-6	ND	1.5 [0.19] (AEGL-2)	4.6 [0.58] (AEGL-3)	Respiratory irritation, lack of data at lower concentrations, occup. max. permissible conc. 0.1 ppm	STEL – 0.2 ppm.
Lewisite 541-25-3	0.003[C]	ND	ND	Irritation: eye and mucous membrane.	No other acute values available.
Lindane 58-89-9	1.5 (TEEL-1)	50 (TEEL-2)	50 (IDLH)	IDLH value based on acute oral data; oral doses of 150 mg/kg have been associated with grand-mal seizures (equivalent to 7000 mg/m^3 for 30 min) (NIOSH 1994).	No other acute values available.
Methyl bromide 74-83-9	58.3 [15] (TEEL-1)	195 [50] (ERPG-2)	777 [200] (ERPG-3)	AIHA determined ERPG-1 was NA based on the lack of detectable odor at low concentrations (poor warning properties). NIOSH (1994) reports that concentrations of 200 ppm may be endured for several hours without serious effects; data mixed.	IDLH – 250 ppm.
Methylene chloride 75-09-2	695 [200] (ERPG-1)	2600 [750] (ERPG-2)	13,880 [4000] (ERPG-3)	Data variable: vertigo, dizziness, nausea may occur at concentrations above 2300 ppm (NIOSH 1994).	IDLH – 2300 ppm.
Methyl hydrazine 60-34-4	ND	1.9 [1] (AEGL-2)	5.7 [3] (AEGL-3)	Known human carcinogen, dermal exposures may contribute to total dose.	PEL – 0.2 ppm, IDLH – 20 ppm.
Methyl isocyanate 624-83-9	0.06 [0.025] (ERPG-1)	0.16 [0.067] (AEGL-2)	0.47 [0.2] (AEGL-3)	Mild, transient eye irritation possible above Minimal effects level. Eye irritation and lacrimation at 5 ppm in less than 50 seconds; unbearable at 21 ppm	ERPG (2-3): 0.5, 5 pmm; IDLH – 3 ppm.

Table C-1: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
				(NIOSH 1994).	
Methyl mercaptan 74-93-1	1 [0.5] (AEGL-1*)	9.8 [5] (AEGL-2*)	45 [23] (AEGL-3*)	Exposures to 4 ppm for several hours have caused headaches and nausea (NIOSH 1994). Minimal effect levels based on low odor threshold that may be perceived as objectionable. ERPG-1 based on low odor threshold.	*Proposed AEGL's published in Fed. Reg. ERPG (1-3): 0.005, 25, 100 ppm, IDLH – 150 ppm; ERPG-1 – 0.005 ppm.
Nitric acid 7697-37-2	1.3 [0.5] (AEGL-1)	10 [4] (AEGL-2)	57 [22] (AEGL-3)	Animals exhibited no adverse effects to concentrations of 24 ppm; maximum allowable workplace value proposed – 10 ppm (NIOSH 1994).	IDLH – 25 ppm; STEL – 4 ppm.
Nitric oxide 10102-43-9	0.61 [0.5*] (AEGL-1*)	15 [12] (AEGL-2*)	25 [20] (AEGL-3*)	Oxides dangerous for exposures between 100 and 150 ppm from 30 – 60 min (NIOSH 1994).	TEEL (1-2): 25, 25 ppm; IDHL – 100 ppm. *Values for nitrogen dioxide adopted due to conversion in atmosphere. No hazard assoc. with short-term exp. to 80 ppm.
Nitrogen dioxide 10102-44-0	0.94 [0.5] (AEGL-1*)	23 [12] (AEGL-2*)	38 [20] (AEGL-3*)	TEELs most appropriate and consistent with other values. Exposure to 10 – 20 ppm mildly irritating; exposure > 150 ppm can cause death from pulmonary edema (NIOSH 1994).	*Proposed AEGL's published in Fed. Reg. TEEL-2 – 15 ppm; IDLH – 20 ppm, EEL – 10 ppm; SPEGL – 1 ppm; STEL – 5 ppm; TEEL-1 – 2 ppm.
Paraquat 4685-14-7	0.15 [0.024] (NIOSH 8-hr PEL)	1.0 [0.16] (IDLH)	***	Toxicity: particle size dependant (< 5 ?) 5-6 times more toxic; under spraying conditions particle sizes are nonrespirable) (NIOSH 1994).	Toxicity based on particle size (see RD 230). 1.5 mg/m³ = IDLH; 0.5 = PEL for TOTAL DUST; 0.1 =PEL for RESPIRABLE FRACTION; excursion limit = 3x TWA; 0.15; [0.024] = TEEL 1-2 *** This chemical must be aerosolilized to inhale – general resulting in relatively brief exposures; severe effects toxicity data is limited to primary route of INGESTION.

Table C-1: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
Parathion 56-38-2	0.3 [0.0024] (TEEL-1)	2 [0.16] (TEEL-2)	10 [0.8] (IDLH)	Workers regularly exposed to 2 to 15 mg/m^3 exhibited only a 25% decrease in cholinesterase; 69 mg/m^3 (extrapolated from an oral dose) may be lethal (NIOSH 1994).	No other acute values available.

Table C-1: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
Perchloromethyl mercaptan 594-42-3	0.11 [0.014] (AEGL-1*)	0.27 [0.035] (AEGL-2*)	2.3 [0.3] (AEGL-3*)	Data show exposures to 25 ppm may be appropriate (NIOSH 1994).	*Proposed AEGL's published in Fed. Reg. IDLH – 10 ppm.
Phosgene 75-44-5	0.4 [0.1] (TEEL-1)	1.2 [0.3] (AEGL-2*)	3.0 [0.75] (AEGL-3*)	Lethal dose to humans for a 30-min exposure was calculated to about 17 ppm; lethality may be evident at lower (5 ppm) concentrations due to pulmonary edema (NIOSH 1994).	*Proposed AEGL's published in Fed. Reg. ERPG (2-3): 0.2, 1 ppm; IDLH – 2 ppm; EEGL – 0.2 ppm.
Phosphine 7803-51-2	NA	0.42 [0.3] (AEGL-2)	1.5 [1.1] (AEGL-3)	Concentrations up to 35 ppm have caused diarrhea, nausea, vomiting, cough, headache, and dizziness; 100 – 200 ppm may be maximum for a duration of 0.5 – 1.0 hrs (NIOSH 1994).	ERPG (2-3): 0.5, 5 ppm; STEL – 1 ppm; IDLH – 50 ppm.
Phosphorus (yellow) 7723-14-0	0.3 (TEEL-1)	3 (TEEL-2)	5 (IDLH)	Single lethal oral doses of 1 mg/kg have been reported; severe symptoms have been reported following a single 15 mg dose (equivalent to 10 mg/m^3 for 30 min); (NIOSH 1994).	No other acute values available.
Phosphorous oxychloride 10025-87-3	NA	NA	5.3 [0.85] (AEGL-3)	Chronic asthmatic-like bronchitis may develop after acute inhalations.	*Proposed AEGL's published in Fed. Reg. STEL – 0.5 ppm.
Phosphorus trichloride 7719-12-2	ND	ND	4.9 [0.88] (AEGL-3)	Concentrations of 1.8 – 27 ppm have been reported to produce burning of the eyes and throat, and mild bronchitis within 2 – 6 hours after exposure (NIOSH 1994).	*Proposed AEGL's published in Fed. Reg. IDLH – 25 ppm, STEL – 0.5 ppm.
Red phosphorus smoke	1 (SPEGL)	10 (EEGL)	1000 (NRC[a])	Lethality, respiratory distress and irritation, pulmonary lesions; severe effects value based on "intolerable" concentration (Mitchell and Burrows 1990); (NRC[a]).	No other acute values available.

Table C-1: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
Selenium hexafluoride 7783-79-1	1.2 [0.15] (TEEL-1)	2 [0.25] (TEEL-2)	16 [2] (IDLH)	Rabbits, mice, rats, and guinea pigs exposed to 5 ppm for 4 hrs developed pulmonary edema of which all survived (NIOSH 1994).	No other acute values available.
Stibine 7803-52-3	ND	2.6 [0.5] (ERPG-2)	7.7 [1.5] (ERPG-3)	Exposures to 40 – 45 ppm for 1 hr in dogs and cats have been reported to be dangerous (NIOSH 1994).	IDLH – 5 ppm.
Sulfur dioxide 7446-09-5	0.8 [0.3] (ERPG-1)	8 [3] (ERPG-2)	39 [15] (ERPG-3)	Maximum concentration for 0.5 – 1.0 hrs was reported to be 50 to 100 ppm (NIOSH, 1994). Minimal effect levels based on increased airway resistance in asthmatics exposed to concentrations above 0.4 ppm.	IDLH – 100 ppm; EEGL – 10 ppm.
Sulfur mustard [HD] 505-60-2	0.067 [0.01] (AEGL-1)	0.10 [0.02] (AEGL-2)	2.1 [0.32] (AEGL-3)	Delayed development of irritation to eyes, mucous membranes; potent alkylating agent; mutagenic. Based on AEGL analysis by NRC (see text for more information); (NRC in press).	(Recommended) IDLH = (2.0) mg/m^3 (no previous existing estimate)
Sulfuric acid 7664-93-9	2 [0.5] (ERPG-1)	10 [2.5] (ERPG-2)	30 [7.5] (ERPG-3)	Variable human responses; 5- to 15-min exposures of 5 mg/m^3 reported to be very objectionable (NIOSH 1994).	IDLH – 15 mg/m^3; STEL – 3 mg/m^3; EEGL – 1 mg/m^3.
Sulfuryl fluoride 2699-79-8	ND	ND	835 [200] (IDLH)	Based on animal data. Less than 5% mortality resulted from 3-hr exposures of 1000 ppm in animals (NIOSH 1998).	STEL – 10 ppm.
Tellurium hexafluoride 7783-80-4	0.6 [0.06] (TEEL-1)	10 [1] (TEEL-2 and IDLH)	**	IDLH = TEEL-2 value; in animals, 1 ppm for 4 hrs caused increased rate of breathing but no mortality levels at 5 ppm and above for 4 hours did resulting animal death (NIOSH 1994).	** Limited data. Suggestion of tolerance – mild effects may dissipate after prolonged exposure. Not clear at what level human fatlities or trult severe effect swould occur (just greater than 1 ppm).

Table C-1: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
Tetrachloroethane (1,1,2,2-) 79-34-5	20.6 [3] (TEEL-1)	3.4 [5] (TEEL-2)	686 [100] (IDLH)	A 30-min exposure to 146 ppm has caused vertigo, irritation, fatigue, head pressure; same effects were noted after a 10-minute exposure to 335 ppm (NIOSH 1994).	No other acute values available.
Tetrachloroethylene (Perchloroethylene) 127-18-4	237 [35] (AEGL-1*)	1560 [230] (AEGL-2*)	3323 [490] (AEGL-3*)	95-min exposures exceeding 1000 ppm produces slight drunkenness, yet no narcosis; 30 min exposures to > 206 ppm may cause dizziness and irritation.	*Proposed AEGL's published in Fed. Reg. ERPG (1-3): 100, 200, 1000 ppm; IDLH – 150 ppm; STEL – 100 ppm.
Tetraethyl lead 78-00-2	0.13 (TEEL-1)	0.75 (TEEL-2)	40 (IDLH)	NIOSH reports that a value of 100 mg/m^3 would have been appropriate for IDLH but not being currently reviewed.	IDLH – 40 mg/m^3.
Tetramethyl lead 75-74-1	ND	ND	40 (IDLH)	NIOSH reports a value of 150 mg Pb/m^3 may be appropriate.	No other acute values available.
Titanium tetrachloride 7550-45-0	5 (ERPG-1)	20 (ERPG-2)	100 (ERPG-3)	At higher concentrations irritation of the respiratory tract and exposed tissue may result. Based on theoretical extrapolation of hydrochloric acid release (AIHA 1999).	No other acute values available.
Toluene 108-88-3	309 [82] (AEGL-1*)	716 [190] (AEGL-2*)	2374 [630] (AEGL-3*)	Eye and respiratory irritation and symptoms of dizziness, fatigue, drowsiness, headache, and feelings of intoxication at the minimal effects level; loss of consciousness to humans at concentrations > 5000 ppm within minutes.	*Proposed AEGL's published in Fed. Reg. ERPG (1-3): 50, 300, 1000 ppm, IDLH – 500 ppm; EEGL – 200 ppm.
Toluene 2,4-diisocyanate 584-84-9	0.14 [0.02] (AEGL-1)	0.59 [0.083] (AEGL-2)	3.6 [0.51] (AEGL-3)	Strong sensitizer; repeated exposures may lower concentration at which effects are experienced.	TEEL (1-2): 0.02, 1 ppm; IDLH – 2.5 ppm; STEL – 0.02 ppm.

Table C-1: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
Trichloroethylene 79-01-6	537 [100] (ERPG-1)	2687 [500] (ERPG-2)	26,870 [5000] (ERPG-3	Exposures of 1000 ppm for 2 hrs caused decrements in perception and motor skills (NIOSH 1994).	IDLH – 1000 ppm; STEL – 100 ppm.
Trichloropropane (1,2,3-) 96-18-4	181 [30] (TEEL-1)	302 [50] (TEEL-2)	603 [100] (IDLH)	Exposures exceeding 100 ppm causes objectionable ocular and mucosal irritation after 15 min.	No other acute values available.
VX 50782-69-9	0.000080 [0.000007] (AEGL-1)	0.00098 [0.00009] (AEGL-2)	0.0033 [0.0003] (AEGL-3)	Levels 1 and 2: Derived by relative potency from study of multiple minimal (1) or transient (2) effects in human volunteers exposed to agent GB; may limit performance for night operations, aircrews, and tasks involving distance or spatial judgement Level 3: Derived by relative potency from study of GB vapor experimental Sprague-Dawley rat lethality data (LC_{01}, LC_{50}) (see text for more information); (EPA 2001).	Existing (Recommended) IDLH = 0.02 (0.01) mg/m^3
Xylene (mixed) 1330-20-7	650 [150] (TEEL-1)	868 [200] (EEGL)	3906 [900] (IDLH)	Exposures of 1000 ppm for 5 min may allow for self-rescue; reaction time not affected in 23 volunteers exposed to 100 or 200 ppm from 3 to 7 hrs (NIOSH 1994).	STEL – 150 ppm.

Table C-1: Basis for 1-hour Short-Term Air-MEGs

Notes:
CAW – Chemical Agent Warfare Technical Report: *Information for Combat Developers on Performance Effects from Exposure to Chemical Warfare Agents,* March 1999.
NRC[a] – National Research Council. 1997. *Toxicity of Military Smokes and Obscurants, Vol. 1*. Committee on Toxicology, National Academy Press, Washington, DC.
NRC—National Research Council, in press. *Acute Exposure Guideline Levels for Selected Airborne Chemicals, Vol. 2*, Committee on Toxicology. National Academy Press, Washington, D.C.AIHA – American Industrial Hygiene Association. 1999, *Emergency Response Planning Guidelines*, AIHA Press, Fairfax, VA.
EPA – Environmental Protection Agency. 2001. "National Advisory Committee for Acute Exposure Guideline Levels (AEGLs) for Hazardous Substances; Proposed AEGL Values" *Federal Register* 66 (85): 21940-21964 (2 May 2001).ACGIH – American Conference of Governmental Industrial Hygienists. 1998, *Threshold Limit Values for Chemical Substances and Physical Agents*, ACGIH Press, OH.
✍- Indicates values less than 1-14 day value, based on objectionable odor, differences in professional judgment between organizations in value derivation, or derived based on applications to sensitive subpopulations (e.g., asthmatics).
CAS No. – Chemcial Abstract Service number
c – Ceiling value.
NA – Not applicable; value determined not appropriate.
ND – Not determined; data not yet evaluated.
Mitchell, W. R., Burows, E. P. 1990. *Assessment of Red Phosphorus in the Environment.* AD-A221704. U.S. Army Biomedical Research & Development Laboratory, Fort Detrick, Frederick, MD 21701-5010.
Shoshkes, M., Banfield, Jr., W.G., and Rosenbaum, S.J. 1950. "Distribution, effect, and fate of oil aerosol particles retained in the lungs of mice." Arch. Ind. Hyg. Occup. Med. 1:20-35 (*in* NRC, 1997a).

Table C-2: Basis for 8-hour and 14-day Short-term Air-MEGs

Chemical CAS No.	8-hour Air-MEG mg/m^3 [ppm]	14-day Air-MEG mg/m^3 [ppm]	Source	Critical Study Endpoint	Notes
Acetone cyanohydrin 75-86-5	8 [2]	0.4 [0.1]	AIHA ACGIH	CNS effects, anoxia.	WEEL / TLVs[?] -Adj. OSHA permissible exposure limit - 5 mg/m^3 (1.3 ppm). NIOSH recommended exposure limit; ceiling value – 1 ppm. Ceiling value derived as CN.
Acrolein 107-02-8	0.07 [0.03]	0.023 [0.01]	AEGL-1 NRC[1]	Irritant; dermal and eye irritation in humans.	ATSDR/MRL - 0.00011 mg/m^3; ACGIH/ TLVs[? CS] – 0.23 mg/m^3.
Acrylonitrile 75-05-8	4.4 [2]	0.22 [0.10]	ACGIH ATSDR	Based on human NOAEL.	ACGIH/ TLVs[?] – 4.4 mg/m^3.
Aldrin 309-00-2	0.25 [0.02]	0.006[S] [0.0004]	ACGIH ACGIH	Based on an exposure designed to prevent liver effects (limited data).	CNS and liver effects may be possible during prolonged exposures; dermal exposure may contribute to overall dose; deposits in subcutaneous fat; carcinogen. TLVs[?] / TLVs[?] -Adj.
Allyl alcohol 107-18-6	4.4 [1.8]	0.012[S] [0.05]	AEGL-1 ACGIH	Mixed; eye irritation, corneal necrosis, lacrimation; visceral congestion, hematuria, nephritis.	Dermal exposures may contribute to overall dose. TLV-Adj.
Ammonia 7664-41-7	17 [25]	0.35 [0.13]	AEGL-1 ATSDR	No effect on pulmonary function.	Based on chronic occupational exposures. ACGIH/TLV – 1.7 mg/m^3.
Arsenic trichloride 7784-34-1	0.01* [0.003]	0.01* [0.003]	ACGIH ACGIH	Irritation of mucous membranes, dermatitis, perforation of nasal septum, pharyngitis and conjunctivitis; value based on industrial concentrations where no effects were found.	Based on arsenic as an inorganic compound; soluble arsenic acutely toxic form; chlorides may induce irritation effects at lower concentrations; data to substantiate this is lacking; carcinogen. *Measured as arsenic.
Arsine 7784-42-1	0.17 [0.05]	0.004 [0.0012]	ACGIH ACGIH	Red blood cell and kidney effects.	Carcinogen. TLV / TLV-Adj.

*Notes for table on page C-2-15.

Table C-2: Basis for 8-hour and 14-day Short-term Air-MEGs

Chemical CAS No.	8-hour Air-MEG mg/m^3 [ppm]	14-day Air-MEG mg/m^3 [ppm]	Source	Critical Study Endpoint	Notes
Benzene 71-43-2	1.6 [0.5]	0.16 [0.05]	ACGIH ATSDR	Based on lymphocyte apoptosis in mice.	TLV: Based on chronic studies where cancer was primary endpoint; TLV approaches odds for those not exposed in the development of cancer.
Boron tribromide 10294-33-4	10^C [1]	10^C [1]	ACGIH ACGIH	Irritation; primary irritant with no known chronic effects.	TLV.
Boron trifluoride 7637-07-2	2 [0.73]	2 [0.73]	ERPG-1 ERPG-1	Irritation; pulmonary irritant leading to pneumonia after repeated exposure; no pathological changes in rats exposed to 6 ppm or 6 hrs/day, 5 day/wk, for 13 wks.	ACGIH ceiling value – 3 mg/m^3.
Bromine 7726-95-6	0.063 [0.095]	0.063 [0.095]	AEGL-1 AEGL-1	Irritant; respiratory passage irritation and lung injury.	ACGIH (TLV) - 0.1 ppm (0.65 mg/m^3)
Bromine pentafluoride 7789-30-2	0.7 [0.1]	0.7 [0.1]	ACGIH ACGIH	Irritant; irritation to upper respiratory passages and eyes.	TLV.
Carbon disulfide 75-15-0	3^S [1]	0.76^S [0.24]	ERPG-1 ACGIH	Systemic; headaches.	Dermal exposures may contribute to overall dose; carcinogen. TLV-Adj.
Carbon monoxide 630-08-0	28 [25]	0.70 [0.61]	ACGIH ACGIH	Systemic; based on blood carboxyhemoglobin levels < 3.5%.	May not be protective of sensitive individuals under conditions of heavy labor, high temperatures, or in elevation >5,000ft. TLV / TLV-Adj.
Carbon tetrachloride 56-23-5	32.5 [5.2]	1.3 [0.2]	ACGIH ATSDR	Systemic; liver toxicity; alcohol potentiation may occur.	ACGIH/TLV - 3.1+01 mg/m^3; carcinogen.
Carbonyl fluoride 353-50-4	5 [2]	0.13 [0.05]	ACGIH ACGIH	Mixed; pulmonary edema; kidney injury; fluorosis.	TLV / TLV-Adj.

Table C-2: Basis for 8-hour and 14-day Short-term Air-MEGs

Chemical CAS No.	8-hour Air-MEG mg/m^3 [ppm]	14-day Air-MEG mg/m^3 [ppm]	Source	Critical Study Endpoint	Notes
Chlorine 7782-50-5	1.5 [0.5]	0.29 [0.1]	AEGL-1 NRC[1]	Irritation; eyes and mucous membrane irritation.	ACGIH/TLV – 1.5 mg/m^3.
Chlorine trifluoride 7790-91-2	0.15 [0.04]	0.15 [0.04]	AEGL-1 AEGL-1	Irritant; lung and mucous membrane injury.	ACGIH ceiling value - 0.1 ppm (0.4 mg/m^3)
Chloroacetaldehyde 107-20-0	3.2[C] [1]	3.2[C] [1]	ACGIH ACGIH	Irritant; pneumonitis, bronchitis; tumor initiator.	ACGIH ceiling value and OSHA Permissible exposure limit. Carcinogen.
Chloroacetone 78-95-5	3.8[C] [1]	3.8[C] [1]	ACGIH ACGIH	Irritation; lacrimation, upper respiratory tract, skin effects.	ACGIH ceiling value.
Chloroacetophenone [CN] 532-27-4	0.32 [0.05]	0.32 [0.05]	ACGIH ACGIH	Irritation, eyes, respiratory tract.	TLV.
Chloroacetyl chloride 79-04-9	0.23 [0.05[S]]	0.23 [0.05[S]]	ACGIH ACGIH	Irritant; eye and respiratory passage irritation.	TLV. Dermal exposures may contribute to overall dose.
Chlorobenzylidene malonitrile (o-) [CS] 2698-41-1	0.39[C] [0.05]	0.39[C] [0.05]	ACGIH ACGIH	Irritation, eye, conjunctiva, nose and throat.	ACGIH ceiling value and OSHA Permissible exposure limit. Potential sensitizer.
Chloroform 67-66-3	48 [10]	0.5 [0.1]	ACGIH ATSDR	Systemic; liver effects; embryotoxic.	TLV; carcinogen.
Crotonaldehyde 4170-30-3	0.54[S] [0.19]	0.54[S] [0.19]	AEGL-1 AEGL-1	Irritation; eyes and respiratory passages, lacrimation.	ACGIH ceiling value - 0.3 pmm, Probable carcinogen. Dermal exposures may contribute to overall dose.

Table C-2: Basis for 8-hour and 14-day Short-term Air-MEGs

Chemical CAS No.	8-hour Air-MEG mg/m^3 [ppm]	14-day Air-MEG mg/m^3 [ppm]	Source	Critical Study Endpoint	Notes
Cyanogen 460-19-5	20 [10]	0.51 [0.24]	ACGIH ACGIH	Mixed; by analogy with hydrogen cyanide to prevent irritation and systemic effects.	TLV / TLV-Adj.
Diborane 19287-45-7	0.1 [0.1]	0.0024 [0.0024]	ACGIH ACGIH	Mixed; neurological effects, respiratory irritant; pulmonary function.	TLV / TLV-Adj.
Dichloroethane (1,1-) 75-34-3	400 [100]	9.8 [2.4]	ACGIH ACGIH	Systemic; liver toxicity.	TLV / TLV-Adj.
Dieldrin 60-57-1	0.25^S [0.02]	0.006^S [0.0004]	ACGIH ACGIH	Based on systemic toxicity; liver effects.	Dermal exposures may contribute to overall dose; ACGIH suggests that the greatest pathway for exposure in an industrial exposure is through the skin; toxic metabolite of aldrin; TLV / TLV-Adj.
Diesel fuel smoke	5	5	NRC[a] NRC[a]	Weight losses and reduced weight gain in rats, focal pneumonitis in rats.	Value based on two 8-hour exposures per week. Critical study endpoint data obtained from Lock et al. (1984) and Dalbey et al. (1982) (*in* NRC[a]).
Dimethyl sulfate 77-78-1	0.5^S [0.1]	0.0012^S [0.0024]	ACGIH ACGIH	Mixed; irritation of eyes and skin; liver and CNS effects.	Dermal exposures may contribute to overall dose. TLV / TLV-Adj.
Endrin 72-20-8	0.1^S [0.008]	0.002^S [0.00016]	ACGIH ACGIH	Based on extrapolation of acute animal data and limited evidence in humans.	Stereoisomer of dieldrin; dermal exposures may contribute to overall dose. TLV / TLV-Adj.
Ethyl benzene 100-41-4	435 [100]	10.5 [2.4]	ACGIH ACGIH	Mixed effects; hepatic, renal, pulmonary, cardiac, and neurological toxicity; narcosis and respiratory irritation; skin notation.	TLV / TLV-Adj.

Table C-2: Basis for 8-hour and 14-day Short-term Air-MEGs

Chemical CAS No.	8-hour Air-MEG mg/m^3 [ppm]	14-day Air-MEG mg/m^3 [ppm]	Source	Critical Study Endpoint	Notes
Ethylenimine 151-56-4	0.92^S [0.5]	0.022^S [0.012]	ACGIH ACGIH	Mixed; CNS effects; liver and kidney effects; respiratory irritation, eye and nose irritation, skin notation.	Dermal exposures may contribute to overall dose. TLV / TLV-Adj.
Ethylene oxide 75-21-8	1.8 [1]	0.04 [0.02]	ACGIH ACGIH	Systemic; mutagen, neurotoxin; liver, kidney and blood effects.	Carcinogen. TLV / TLV-Adj.
Fluorine 7782-41-4	1.6 [1]	1.6 [1]	AEGL-1 ACGIH	Irritant; eye, mucous membrane, and skin irritation.	TLV.
Fog oil smoke	5	5	NRC[a] NRC[a]	Discomfort threshold.	Based on Hendricks et al. (1962) (*in* NRC[a]).
Formaldehyde 50-00-0	0.37^C [0.3]	0.37^C [0.3]	ACGIH ACGIH	Irritation; eye, nose, throat, and upper respiratory tract irritation; dermatitis; rhinitis; conjunctivitis, and asthma.	ACGIH ceiling value. Carcinogen.
GA (Tabun) 77-81-6	0.001 [0.00015]	0.0003 [0.00005] (Level-1) 0.004 [0.00067] (Level-2) 0.03 [0.005] (Level - 3)	EPA 2001; text of this document	Based on relative potency from GB. Derived from 8-hr AEGL	24-hour MAGs estimate derived from 8-hour AEGL by straightline extrapolation of 8-hour AEGL Ct (see EPA 2001 and document text) Existing (Recommended) GPL = 0.000003 (0.000003) mg/m3 Existing (Recommended) WPL = 0.0001 (0.0001) mg/m3

Table C-2: Basis for 8-hour and 14-day Short-term Air-MEGs

Chemical CAS No.	8-hour Air-MEG mg/m^3 [ppm]	14-day Air-MEG mg/m^3 [ppm]	Source	Critical Study Endpoint	Notes
GB (Sarin) 107-44-8	0.001 [0.00017]	0.0003 [0.000057] (Level-1) 0.004 [0.00073] (Level-2) 0.02 [0.0029] (Level-3)	EPA 2001; text of this document	Level-1: Reversible miosis, headache, eye pain, rhinorrhea, tightness in chest, cramps, nausea, malaise, miosis in human volunteers; may limit performance for night operations, aircrews, and tasks involving distance or spatial judgement Level-2: Reversible miosis, dyspnea, RBC-ChE inhibition, single fibre electromyography (SFEMG) changes in human volunteers; may limit performance for night operations, aircrews, and tasks involving distance or spatial judgement Level-3: Based on experimental Sprague-Dawley rat lethality data (LC_{01}, LC_{50}) Derived from 8-hr AEGL	24-hour MAGs estimate derived from 8-hour AEGL by straightline extrapolation of 8-hour AEGL Ct (see EPA 2001 and document text) Existing (Recommended) GPL = 0.000003 (0.000003) mg/m3 Existing (Recommended) WPL = 0.0001 (0.0001) mg/m3

Table C-2: Basis for 8-hour and 14-day Short-term Air-MEGs

Chemical CAS No.	8-hour Air-MEG mg/m^3 [ppm]	14-day Air-MEG mg/m^3 [ppm]	Source	Critical Study Endpoint	Notes
GD (Soman) 96-64-0	0.0005 [0.000065]	0.000022 (0.0002) (Level-1) 0.00028 (0.002) (Level-2) 0.0022 (0.02) (Level-3)	EPA 2001; text of this document	Based on relative potency from GB. Derived from 8-hr AEGL	**24-hour MAGs estimate** derived from 8-hour AEGL by straightline extrapolation of 8-hour AEGL Ct (see EPA 2001 and document text) Existing (Recommended) GPL = 0.000003 (0.000001) mg/m3 Existing (Recommended) WPL = 0.00003 (0.00003) mg/m3
GF 329-99-7		0.0002 [0.000023] (Level-1) 0.002 [0.00030] (Level-2) 0.02 [0.0024] (Level-3)	EPA 2001; text of this document	Based on relative potency from GB. Derived from 8-hr AEGL	**24-hour MAGs estimate** derived from 8-hour AEGL by straightline extrapolation of 8-hour AEGL Ct (see EPA 2001 and document text) (Recommended) GPL = (0.000001) mg/m3; no previous existing value (Recommended) WPL = (0.00003) mg/m3; no previous existing value
Hexachlorobutadiene 87-68-3	0.24 [0.02]	0.005^S [0.0005]	ACGIH ACGIH	Systemic; kidney effects; no human data; based on a NOEL of 0.2 mg/kg/day after continuous ingestion by rats for 2 yrs.	Dermal exposures may contribute to overall dose; carcinogen. TLV / TLV-Adj.
Hexachlorocyclopentadiene 77-47-4	0.1 [0.01]	0.1 [0.01]	ACGIH ACGIH	Irritant; skin and mucous membrane irritation, lacrimation, sneezing, and salivation; higher concentrations cause pulmonary hyperemia and edema.	TLV.

Table C-2: Basis for 8-hour and 14-day Short-term Air-MEGs

Chemical CAS No.	8-hour Air-MEG mg/m^3 [ppm]	14-day Air-MEG mg/m^3 [ppm]	Source	Critical Study Endpoint	Notes
Hexachloroethane smoke 67-72-1	0.2	0.2	NRC[a] NRC[a]	In mice; respiratory distress, edema of the lungs, destructive alveolitis, and macrophage infiltration, followed by development of fibrosis.	Based on data for $ZnCl_2$, Marrs et al. (1988) (*in* NRC[a]).
Hexane 110-54-3	180[S] [50]	4.3[S] [1.2]	ACGIH ACGIH	Systemic; polyneuropathy; based on the conclusion that solvents contain 50% to 70% n-hexane.	Dermal exposures may contribute to overall dose. TLV / TLV-Adj.
Hydrazine 302-01-2	0.13[S] [0.1]	0.013[S] [0.01]	AEGL-1 ACGIH	Based on a slightly higher incidence of nasal tumors in rats exposed to 0.05 ppm.	Given the application of the given exposure period (equivalent to 1/70th of the exposure period); no UF was applied.
Hydrogen bromide 10035-10-6	9.9[C] [3]	9.9[C] [3]	ACGIH ACGIH	Irritant; nose, throat, and eye irritation.	ACGIH ceiling value and OSHA Permissible exposure limit.
Hydrogen chloride 1333-74-0	2.7 [1.8]	2.7 [1.8]	AEGL-1 AEGL-1	Irritant; eye, mucous membrane, and skin irritation.	5 ppm ACGIH [C]
Hydrogen cyanide 74-90-8	1.1[S] [1]	0.11[S] [0.11]	AEGL-1 ACGIH	Mixed; CNS, headache, tachycardia, nausea; nasal irritation.	Given the possibility of bioaccumulation from continuous exposures and the magnitude of effect, TLV-Adj. Dermal exposures may contribute to overall dose.
Hydrogen fluoride 7664-39-3	0.41 [0.5]	0.41 [0.5]	AEGL-1 AEGL-1	Irritant; respiratory irritation; in solution, burns to the skin and eyes.	3 ppm ACGIH [C]
Hydrogen selenide 7783-07-5	0.2 [0.05]	0.2 [0.05]	ACGIH ACGIH	Irritation; eye and mucous membrane.	*Measured as selenium. TLV.

Table C-2: Basis for 8-hour and 14-day Short-term Air-MEGs

Chemical CAS No.	8-hour Air-MEG mg/m^3 [ppm]	14-day Air-MEG mg/m^3 [ppm]	Source	Critical Study Endpoint	Notes
Hydrogen sulfide 7783-06-4	0.15 [0.11]	0.15 [0.11]	AEGL-1 AEGL-1	Mixed; eye irritation; neuroasthenic symptoms such as headache, dizziness, and irritability; CNS effects.	TLV (ACGIH) – 10 ppm; TLV-Adj. – 0.12 ppm.
Iron pentacarbonyl 13462-40-6	0.8 [0.1]	0.02 [0.0024]	ACGIH ACGIH	Mixed; respiratory distress, cyanosis, tremors, and paralysis of the extremities in animals.	* Measured as Fe. TLV / TLV-Adj.
Lewisite 541-25-3	0.003^C	0.003^C	DA PAM 50-6	Irritation: eye and mucous membrane.	Value represents a technologically feasible "real-time" detection limits. Based on inference from available toxicity information.
Lindane 58-89-9	0.5^S [0.04]	0.012^S [0.001]	ACGIH ACGIH	Based on a LOAEL of 0.19 – 0.7 mg/m^3 for CNS effects.	TLV / TLV-Adj.; dermal exposures may contribute to overall dose.
Methyl bromide 74-83-9	4^S [1]	0.09^S [0.024]	ACGIH ACGIH	Systemic; pulmonary edema, neurotoxic effects.	TLV / TLV-Adj.; dermal exposures may contribute to overall dose; carcinogen.
Methylene chloride 75-09-02	175 [50]	2.1 [0.6]	ACGIH *PMAG	Based on human behavioral data.	ACGIH/TLV - 175 mg/m^3; carcinogen. *See TG230B for description.
Methyl hydrazine 60-34-4	0.02^S [0.01]	0.0005^S [0.00024]	ACGIH ACGIH	Systemic; hemolytic anemia.	TLV / TLV-Adj.; dermal exposures may contribute to overall dose; carcinogen.
Methyl isocyanate 624-83-9	0.05^S [0.02]	0.05^S [0.02]	ACGIH ACGIH	Irritant; corrosive and irritating to the mucous membranes; sensitization of the pulmonary tract.	TLV. Dermal exposures may contribute to overall dose.
Methyl mercaptan 74-93-1	1 [0.5]	0.024 [0.012]	AEGL-1 ACGIH	Mixed; eye and mucous membrane irritation; CNS depression.	TLV-Adj.

Table C-2: Basis for 8-hour and 14-day Short-term Air-MEGs

Chemical CAS No.	8-hour Air-MEG mg/m^3 [ppm]	14-day Air-MEG mg/m^3 [ppm]	Source	Critical Study Endpoint	Notes
Nitric acid 7697-37-2	1.3 [0.5]	1.3 [0.5]	AEGL-1 AEGL-1	Irritant; eye and mucous membrane irritant, corrosion of the teeth and skin; pulmonary edema.	ACGIH TLV – 2 ppm.
Nitric oxide 10102-43-9	0.61 [0.5]	0.61 [0.5]	AEGL-1* AEGL-1*	Systemic; methemoglobinemia, CNS effects.	* Proposed AEGL, based on value for nitrogen dioxide due to conversion in atmosphere. TLV-Adj. – 0.6 ppm (ACGIH).
Nitrogen dioxide 10102-44-0	0.94 [0.5]	0.94 [0.5]	AEGL-1* AEGL-1*	Irritant; mildly irritating to the eyes, nose, and upper respiratory tract; bronchitis and emphysema.	*Proposed AEGL, TLV – 3 ppm (ACGIH).
Paraquat 4685-14-7	0.1 [0.016]	0.01 [0.0016]	ACGIH ACGIH	Based on systemic toxicity of respirable fraction (<5 ?m) TLV = 0.5 mg/m^3.	TLV / TLV-Adj.; toxicity dependant on particle size, particles <5 µm.
Parathion 56-38-2	0.1^S [0.008]	0.0024^S [0.0002]	ACGIH ACGIH	Systemic; anticholinesterase activity.	TLV / TLV-Adj.; dermal exposures may contribute to overall dose.
Perchloromethyl mercaptan 594-42-3	0.05 [0.006]	0.05 [0.006]	AEGL-1* AEGL-1*	Irritant; eye, nose, and throat irritation; at higher concentrations may cause coughing, dyspnea, lacrimation, pallor, vomiting, tachycardia, cyanosis.	*Proposed AEGL; TLV- 0.1 ppm (ACGIH).
Phosgene 75-44-5	0.4 [0.1]	0.04 [0.01]	ACGIH NRC[1]	Mixed; pulmonary edema, anoxia.	ACGIH/TLV – 0.10 ppm.
Phosphine 7803-51-2	0.4 [0.3]	0.01 [0.0073]	ACGIH ACGIH	Mixed; severe respiratory irritant; gastrointestinal, respiratory, and CNS effects noted at concentrations < 10 ppm (14 mg/m^3).	TLV / TLV-Adj.; does not account for chronic phosphorus poisoning.

Table C-2: Basis for 8-hour and 14-day Short-term Air-MEGs

Chemical CAS No.	8-hour Air-MEG mg/m^3 [ppm]	14-day Air-MEG mg/m^3 [ppm]	Source	Critical Study Endpoint	Notes
Phosphorus (yellow) 7723-14-0	0.1 [0.02]	0.0024 [0.0005]	ACGIH ACGIH	Acute effects; respiratory irritation, nausea, hepatic and renal necrosis.	TLV / TLV-Adj.; severe symptoms in man at relatively low, single doses (15 mg); chronic effects not well characterized.
Phosphorus oxychloride 10025-87-3	0.6 [0.1]	0.015 [0.002]	ACGIH ACGIH	Mixed; eyes, mucous membrane, and skin irritation; kidney effects.	TLV / TLV-Adj..
Phosphorus trichloride 7719-12-2	1.5 [0.2]	1.5 [0.2]	ACGIH ACGIH	Irritant; severe irritation of the eyes, mucous membranes, and skin.	TLV.
Red phosphorus smoke	1	1	NRC[a] NRC[a]	Eye and skin irritation, pulmonary effects.	Based on the ACGIH TLV-TWA for phosphoric acid, the main combustion product of concern.
Selenium hexafluoride 7783-79-1	0.4 [0.05]	0.4 [0.05]	ACGIH ACGIH	Irritation; based on acute toxicity, pulmonary edema.	* Measured as Se. TLV.
Stibine 7803-52-3	0.5 [0.1]	0.5 [0.1]	ACGIH ACGIH	Irritant; pulmonary irritation; kidney and liver damage at higher concentrations.	TLV.
Sulfur dioxide 7446-09-5	0.8 [0.3]	0.8 [0.3]	ERPG-1 ERPG-1	Irritant; mild respiratory irritation and human bronchoconstriction.	ACGIH/TLV – 5.2 mg/m^3. NRC – 1 ppm.

Table C-2: Basis for 8-hour and 14-day Short-term Air-MEGs

Chemical CAS No.	8-hour Air-MEG mg/m^3 [ppm]	14-day Air-MEG mg/m^3 [ppm]	Source	Critical Study Endpoint	Notes
Sulfur mustard [HD] 505-60-2	0.0083 [0.0012]	0.003 [0.00033] (Level-1) 0.004 [0.00067] (Level-2) 0.09 [0.013] (Level-3)	NRC in press; text of this document	Level 1: **Delayed development** (hours post-exposure) of conjunctival injection and minor discomfort with no functional decrement in human volunteers in hot-weather conditions; greater concentrations tolerated in cold-weather conditions. Level 2: **Delayed development** (hours post-exposure) of well-marked, generalized conjunctivitis, edema, photophobia, and eye irritation in human volunteers in hot-weather conditions; greater concentrations tolerated in cold-weather conditions Level 3: Based on experimental lethality data for Swiss mice Derived from 8-hr AEGL	**24-hour MEGs estimate** derived from 8-hour AEGL by straightline extrapolation of 8-hour AEGL Ct (see NRC in press and document text) Existing (Recommended) GPL = 0.0001 (0.00002) mg/m3 Existing (Recommended) WPL = 0.003 (0.0004) mg/m3 Carcinogen.
Sulfuric acid 7664-93-9	1 [0.25]	1 [0.25]	ACGIH ACGIH	Irritant; pulmonary irritation.	TLV. Carcinogen.

Table C-2: Basis for 8-hour and 14-day Short-term Air-MEGs

Chemical CAS No.	8-hour Air-MEG mg/m^3 [ppm]	14-day Air-MEG mg/m^3 [ppm]	Source	Critical Study Endpoint	Notes
Sulfuryl fluoride 2699-79-8	20 [5]	0.5 [0.12]	ACGIH ACGIH	CNS depressant and pulmonary irritant in animals.	TLV / TLV-Adj.
Tellurium hexafluoride 7783-80-4	0.2 [0.02]	0.2 [0.02]	ACGIH ACGIH	Irritant; pulmonary irritation in animals; in humans, respiratory tract irritation and intoxication.	*Measured as tellurium. TLV.
Tetrachloroethane (1,1,2,2-) 79-34-5	7^S [1]	0.2^S [0.024]	ACGIH ACGIH	Systemic; nervous, hepatic, and gastrointestinal effects.	TLV / TLV-Adj.; dermal exposures may contribute to overall dose.
Tetrachloroethylene (Perchloroethylene) 127-18-4	81 [12]	4.2 [0.61]	AEGL-1 ACGIH	Systemic; liver injury.	TLV-Adj.
Tetraethyl lead* 78-00-2	0.1^S [0.013]	0.0024^S [0.0003]	ACGIH ACGIH	Tinnitus, ataxia, tremors, insomnia, psychosis, mania, and convulsions.	*Measured as total Pb (no speciation); guideline based on most toxic Pb species. TLV / TLV-Adj.; dermal exposures may contribute to overall dose.
Tetramethyl lead* 75-74-1	0.1^S [0.013]	0.0024^S [0.0003]	ACGIH ACGIH	Headache, nausea, and convulsions.	*Measured as total Pb (no speciation); guideline based on most toxic Pb species. TLV / TLV-Adj. - 0.0004 ppm.
Titanium tetrachloride 7550-45-0	0.5	0.012	AIHA AIHA	Respiratory tract, skin, and eye irritation. (AIHA 1999).	AIHA WEEL / WEEL-Adj.
Toluene 108-88-3	109 [29]	11 [3]	AEGL-1 ATSDR	Mixed; skin irritation and CNS effects.	ACGIH/TLV - 1.9E+02 mg/m^3.
Toluene 2,4-diisocyanate 584-84-9	0.07 [0.01]	0.036 [0.005]	AEGL-1 ACGIH	Irritant; cough, phlegm production, breathlessness, and wheezing, bronchitis.	Potential sensitizer.
Trichloroethylene 79-01-6	270 [50]	6.6 [1.2]	ACGIH ACGIH	Headache, fatigue, and irritability.	TLV / TLV-Adj.

Table C-2: Basis for 8-hour and 14-day Short-term Air-MEGs

Chemical CAS No.	8-hour Air-MEG mg/m^3 [ppm]	14-day Air-MEG mg/m^3 [ppm]	Source	Critical Study Endpoint	Notes
Trichloropropane (1,2,3-) 96-18-4	60^S [10]	1.5^S [0.24]	ACGIH ACGIH	Systemic; hepatic and renal injury.	TLV / TLV-Adj.; dermal exposures may contribute to overall dose; carcinogen.
Tungsten hexafluoride 7783-82-6	1 [0.125]	0.024 [0.003]	ACGIH ACGIH	Mixed; anorexia, colic, incoordination of movement, trembling, and dyspnea (CNS).	TLV / TLV-Adj., TLV based on soluble tungsten.
VX 50782-69-9	0.000028 [0.0000026]	0.000009 [0.0000009] (Level-1) 0.0001 [0.000011] (Level-2) 0.0004 [0.000040] (Level-3)	EPA 2001; text of this document	Levels 1 and 2: Derived by relative potency from study of multiple minimal (1) or transient (2) effects in human volunteers exposed to agent GB; may limit performance for night operations, aircrews, and tasks involving distance or spatial judgement Level 3: Derived by relative potency from study of experimental Sprague-Dawley rat lethality data (LC_{01}, LC_{50}) Derived from 8-hr AEGL	24-hour MAGs estimate derived from 8-hour AEGL by straightline extrapolation of 8-hour AEGL Ct (see EPA 2001 and document text) Existing (Recommended) GPL = 0.000003 (0.0000003) mg/m3 Existing (Recommended) WPL = 0.00001 mg/m3
Xylene (mixed) 1330-20-7	435 [100]	10.6 [2.4]	ACGIH ACGIH	Mixed; eye, skin, and mucous membrane irritation; hepatic and renal; neurological impairments.	TLV / TLV-Adj.

Table C-2: Basis for 8-hour and 14-day Short-term Air-MEGs

Chemical CAS No.	8-hour Air-MEG mg/m^3 [ppm]	14-day Air-MEG mg/m^3 [ppm]	Source	Critical Study Endpoint	Notes

Notes:

ACGIH – American Conference of Governmental Industrial Hygienists. 1996. *Threshold Limit Values for Chemical Substances and Physical Agents,* Cincinnati, OH.

EPA – Environmental Protection Agency. 2001. "National Advisory Committee for Acute Exposure Guideline Levels (AEGLs) for Hazardous Substances; Proposed AEGL Values" *Federal Register* 66 (85): 21940-21964 (2 May 2001).

NRC—National Reseach Council, in press. *Acute Exposure Guideline Levels for Selected Airborne Chemicals, Vol. 2*, Committee on Toxicology. National Academy Press, Washington, D.C.

NRC[a]– National Research Council. 1997. *Toxicity of Military Smokes and Obscurants, Vol. 1*. Committee on Toxicology, National Academy Press, Washington, DC.

NRC[1] – National Research Council. 1984. *Emergency and Continuous Exposure Limits for Selected Airborne Contaminants*, National Academy of Sciences. AD-A142-133, Vols. 1-3.

ATSDR – Agency for Toxic Substances and Disease Registry. *Acute Minimal Risk Levels (MRLs).* Toxicological Profiles. U.S. Public Health Service.

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DA PAM 50-6, *Update, Chemical Agent Incident Response and Assistance (CAIRA) Operations*. 17 May 1991.

C – Ceiling value (ACGIH, 1998).

CAS No. – Chemical Abstract Service number

s – Skin notation; dermal exposures have the potential for significant contribution to overall dose.

CNS – Central Nervous System.

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Marrs, T.C., Colgrave, H.F., Edington, J.A.G., Brown, R.F.R., and Cross, N.L. 1988. "The repeated dose toxicity of a zinc oxide/hexachloroethane smoke." Arch. Toxicol. 62:123-132 (*in* NRC 1997a).

APPENDIX D

DERIVATION OF MILITARY EXPOSURE GUIDELINES FOR WATER

Table D-1: Selecting Chemicals Of Concern In Drinking Water – An Assessment of "Lists"

Chemical CAS No.	ITF 25	TB MED 577	EPA/ Army	TRI	PIC	POP	LL	WHO	ATSDR gw/sw	Short-Term Water-MEG (mg/L)
Alachlor 15972-60-8								X		0.14
Aldrin 309-00-2				Low	X	X		X	8/2	0.0004
Benzene 71-43-2				Top 75					115/41	0.1
Carbofuran 1553-66-2							X	X		0.07
Carbon disulfide 75-15-0	X			Top 75				X		0.14**
Chlordane 57-74-9				Low	X	X		X		0.09
Chloride 16887-00-6	As chlorine	X		Top 21 as chlorine						600
Chloromethane [Methyl chloride)] 74-87-3				Top 34						0.5
Chromium (total) 7440-47-3				Top 21 as Cr cpds					93/55	2
Cyanide 21725-46-2	As HCN	X		Top 34					13/9	6
2,4-D 94-75-7								X		0.4

Table D-1: Selecting Chemicals of Concern in Drinking Water – An Assessment of "Lists"

Chemical CAS No.	ITF 25	TB MED 577	EPA/ Army	TRI	PIC	POP	LL	WHO	ATSDR gw/sw	Short-Term Water-MEG (mg/L)
Diazinon 333-41-5										**0.03**
Dibromochloropropane 96-12-8								**X**		**0.28**
Dieldrin 60-57-1					**X**	**X**		**X**	**8/2**	**0.007**
Dinitrobenzene (1,3-) 99-65-0			**X**	**Top 34**						**0.06**
Dinoseb 88-85-7					**X**					**0.42**
Dioxane (1,4-) 123-91-1				**Top 21**						**0.56**
Disulfoton 298-04-4								**X**		**0.014**
Ethylene dibromide 106-93-4					**X**			**X**		**0.01**
Endrin 72-20-8						**X**		**X**		**0.02**
Fenamiphos 22224-92-6								**X**		**0.013**
Fonofos 944-22-9								**X**		**0.03**

Table D-1: Selecting Chemicals of Concern in Drinking Water – An Assessment of "Lists"

Chemical CAS No.	ITF 25	TB MED 577	EPA/ Army	TRI	PIC	POP	LL	WHO	ATSDR gw/sw	Short-Term Water-MEG (mg/L)
GA [Tabun[77-81-6		**X**								**0.14***
GB [Sarin[107-44-8		**X**								**0.028***
GD [Soman[96-64-0		**X**								**0.012***
Heptachlor 76-44-8				**Low**	**X**	**X**		*X*	**2/0**	**0.014**
Heptachlor epoxide 1024-57-3						**X**			**2/0**	**0.014***
Hexachlorobenzene 118-74-1				**Top 145**	**X**			**X**		**0.08**
Lewisite 542-25-3		**X**			**X**					**0.027***
Lindane 58-89-9		**X**		**None**				**X**		**0.6**
Magnesium 7439-95-4		**X**								**100**
Malathion 121-75-5										**0.3**
Methylparathion 298-00-0								**X**		**0.4**

Table D-1: Selecting Chemicals of Concern in Drinking Water – An Assessment of "Lists"

Chemical CAS No.	ITF 25	TB MED 577	EPA/ Army	TRI	PIC	POP	LL	WHO	ATSDR gw/sw	Short-Term Water-MEG (mg/L)
Molybdenum trioxide 7439-98-7				**Top 34**						**0.03**
Oxamyl [Vydate] 23135-22-0										**0.35**
Paraquat 1910-42-5								**X**		**0.14**
Simazine 122-34-9								**X**		**0.03**
Sulfate 14808-79-8	**As H_2SO_4**	**X**		**Top 21 as H_2SO_4**						**300**
Sulfur mustard [HD] 505-60-2		**X**								**0.14***
TCDD (2,3,7,8-) 1746-01-6						**X**			**5/3**	**1**
Terbufos 13071-79-9								**X**		**0.007**
Trifluralin 1582-09-8								**X**		**0.1**
VX 50782-69-9		**X**								**0.015***

APPENDIX E
DERIVATION OF MILITARY EXPOSURE GUIDELINES FOR SOIL

APPENDIX F
THE ROLE OF SUSCEPTIBILITY IN ESTABLISHING EXPOSURE STANDARDS FOR DEPLOYED TROOPS

A USACHPPM White Paper

The Role of Susceptibility in Establishing Exposure Standards for Deployed Troops

White Paper December 2001

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Background. During Operation Desert Shield/Desert Storm, the medical community braced itself for casualties. They were surprisingly few in number. The disease and non-battle-injury rate (DNBI) was the lowest in recorded history, probably due to the unique circumstances such as a prohibition on alcohol use and extremely limited contact with the local population. Somewhat unexpected were the complaints of symptoms in returning troops that remain essentially unresolved ten years later, despite several hundred million dollars in research, and over 60,000 evaluations as part of registries.[1-2] With the aim of circumventing such conundrums, numerous panels and committees made recommendations to the DOD.[3-7] Presuming that symptomatic outcomes were related to measurable or identifiable exposures during the deployment, systematic evaluation was limited by exposure data. Accordingly, all recommendations addressed the need for data collection on deployments.

Exposure Standards. While collecting exposure data may be necessary to classify individuals for epidemiological studies, the data is only immediately useful if it can be compared to a standard to benchmark acceptability/permissibility/degree of risk associated with the concentration. Levels of potential exposure vary with the scenario, and levels considered acceptable may vary with the target population. (Figure 1, scale of exposures) The Occupational Safety and Health Administration (OSHA) and the American Conference of Governmental Industrial Hygienists (ACGIH) have developed concentrations for hundreds of chemicals that are considered acceptable for working populations for eight hours per day, daily, for a working lifetime.[8] These are known as Permissible Exposure Limits (PELs) and Threshold Limit Values (TLVs), respectively. ACGIH values are consensus based and typically selected to prevent acute effects for irritants although some are based on more chronic endpoints. Most of the TLVs were recommended in the 1960's and 1970's. It has been claimed that whenever these limits have been implemented in a particular industry, no worker has been shown to have sustained serious adverse effects on health as a result of exposure to TLV concentrations.[9] While the degree of protection may be variable, the adoption of TLVs greatly reduced the incidence of occupational disease. In the late 1980's there were criticisms that they were not well based in science, that the margins of safety inherent in the various TLVs were inconsistent, that industry had undue influence on the committee, and that objective analysis had not been conducted.[10] In 1990 it was shown that for many of the irritants and systemic toxicants, the TLVs were at or near a concentration 10-50 percent of the population could be expected to experience some adverse health effect.[11] The authors reviewed the basis for the TLV and particularly the incidence of adverse effects and the corresponding exposure data. They concluded that the TLVs were poorly correlated with the incidence of adverse effects, that the TLVs were well correlated with the exposure levels which had been reported at the time that the levels were adopted, and that interpretations of exposure-response relationships were inconsistent between the authors of the individual studies and the TLV committee. Taken together, these observations suggest that the TLVs could not have been based purely on the consideration of health.[12] Responding to this criticism, the TLVs adopted in the early 1990's were more likely to be protective of a greater percentage of the working population. The formaldehyde value went from 2.0 ppm to a ceiling of 0.3 ppm, which was estimated to be protective of 95% of the population. A review of the documentation for this value indicates that it should be protective of as much as 99% of the exposed population. [13] It has been estimated that to achieve the protection of 95% of the working population, the TLVs for irritants might need to be reduced by 10 to 50 fold, factoring inter-individual differences in susceptibility. OSHA standards are designed to prevent similar effects, but also take feasibility and detection limits into consideration, and many are simple adoption of TLVs. However, while some changes to the TLVs come out annually, OSHA cannot update TLVs turned into PELs as the yearly TLV revisions occur. [14.] Both values have increasingly considered carcinogenic risk in recent standards, particularly in the past ten years. Theoretical cancer risks associated with TLVs are centered at from 1 in 10 to 1 in 1000 excess cancers. During the early 1980's, limits were set with the consideration that though they were not completely without risk, the risks were comparable to other occupational hazards such as falls, electrocutions, etc.[15] This risk is estimated to be 1 in 1000. While no absolute acceptable cancer risk

has been identified, acceptable cancer risk for exposures to the general public are typically in the 1 in 10,000 to 1 in 1,000,000 range. Regulatory agencies that have establish exposure limits for carcinogens have set limits with a cancer risk ranging from 4 in 10 to 1 in 10,000.[16]

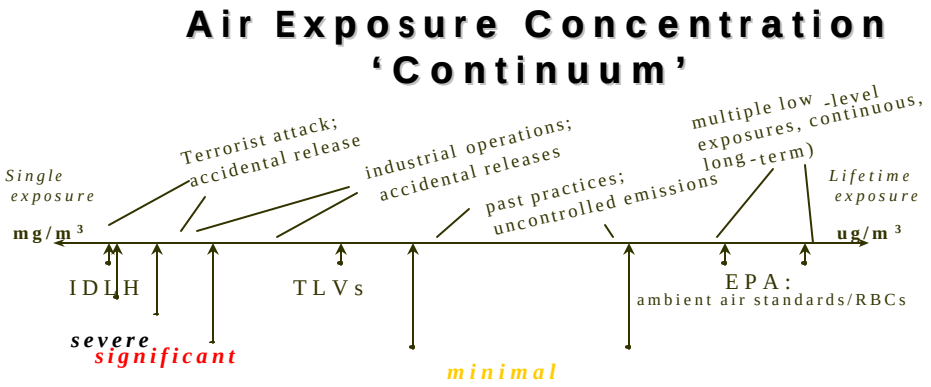

Figure 1. Air Exposure Concentration Continuum

Both sets of values are designed for workers, typically considered a healthy population. This is based on an assumption that workers are screened in some fashion prior to employment, may receive medical surveillance periodically designed to detect disease early, and are healthy enough to show up for work each day (the "healthy worker effect").[17] In reality, many workers receive no specific pre-employment screening and no specific periodic surveillance, and may have a condition that was not present at the time of hiring or may be working with an undiagnosed condition, particularly as they age. Indeed, any selection advantage that would lead to superior health predictably declines with advancing age. In addition to varying with age, the magnitude of the healthy worker effect varies with race and work-status groups.

These values serve as a basis for decision-making; measured concentrations below the action limit require no action, whereas those above may dictate specific periodic follow-up. Although the advantage of these "occupational" values is that they are readily interpretable and useful in decision-making, they are generally not considered appropriate for deployed populations. The most fundamental shortcoming is that they are derived to be acceptable for eight hour per day exposures and deployed troops could be exposed to ambient concentrations 24 hours per day. Further, exposures during deployments may involve other scenarios such as relatively high exposures sustained for short periods, continuous exposures for varying time periods such as 24 hour to 2 weeks at a transient site, or up to one year for a sustained deployment. To evaluate short-term exposures, ACGIH has derived fifteen minute Short Term Exposure Limits (STELs) for workers. These concentrations are not no-effect levels, but derived so as to protect against irritation, chronic or irreversible tissue damage and narcosis or impairment in the ability to work. A more appealing set of values has been derived for some chemicals, although designed for the general population. In 1995, the National Advisory Committee for Acute Exposure Guideline Levels for Hazardous Substances was established to identify, review and interpret relevant toxicological and other scientific data and to develop these guideline levels for high-priority, acutely toxic chemicals. These values represent threshold exposure limits (exposure levels below which adverse health effects are not likely to occur and their utility is based on the fact that they address three levels of effect: mild and reversible, irreversible and serious, and life threatening.[18] Additionally, the AEGLs specifically address time periods ranging from 10 minutes to eight hours by chemical-specific time extrapolation, a feature that no other set of values provide. The previous name for these values was Community Emergency Exposure Levels (CEELS), but this term was replaced by AEGL to reflect the broader applicability of these values to planning and response and prevention in the community, the workplace, transportation the military and remediation of Superfund sites. For longer-term continuous exposures, the Environmental Protection Agency has derived Reference Concentrations, or

RfCs, that represent airborne concentrations that are considered acceptable for the general population to be exposed to for 24 hours per day for a lifetime.[19] These are used in selecting appropriate clean up levels at Superfund sites, or assessing potential health effects from such exposures. Thus, the AEGLs represent a source of short-term exposure levels with possible application to the deployed military, and RfCs represent continuous exposure levels, which may be useful for long-term deployments.

Issues in Applying Exposure Standards to Deployed Troops.

Unlike the OSHA PELs or the ACGIH TLVs, when the AEGLs or PELS are considered for military application, particularly in deployed settings, an initial concern raised is that they are "too conservative." The source of this concern is twofold: they are derived from data by applying uncertainty factors, and they are designed to protect the general population. Values derived by OSHA and ACGIH identify concentrations "that nearly all workers may be repeatedly exposed day after day without adverse effect " and are derived without the standard application of uncertainty factors. AEGLs and RfCs utilize uncertainty factors that are necessary reductions to account for the lack of data and inherent uncertainty in extrapolations from Lowest Observable Adverse Effect Levels (LOAELs) and No Observable Adverse Effect Levels (NOAELs). [20] The most typical uncertainty factors reduce concentrations by a factor of 10. There are five areas of uncertainty addressed, and each may utilize a factor of 10. They relate to interspecies variability (if animal studies are used), human variability, and adjustment for use of a LOAEL instead of a NOAEL, use of sub-chronic data and an incomplete database. It has been stated that the default value of 10 tends to be protective from the standpoint of the behavior of the average chemical. As the composite UF increases in number, the potential for overprotection increases substantially.[21] Additionally, "sub-threshold doses are considered …to be below the population threshold. However, the degree to which doses are below the population threshold is generally not known." In the definition of a reference dose or concentration (RfC), the Environmental Protection Agency notes that the uncertainty spans perhaps an order of magnitude.[19] This has several interpretations, but the most common is that an RfC of 1 mg/m3 may have a range of 0.3 to 3 mg/m3 (that is, half an order of magnitude above and below.)

Human Variability/Susceptibility.

Of particular interest to this discussion is the inter-human variability uncertainty factor. This factor assumes that there is variability in response from one human to the next and that this variability was not detected in the study, usually due to small sample size. This factor may also assume that subpopulations of humans exist that are more sensitive or susceptible to the toxicity of the chemical than the average population.[21] The term susceptibility is often used to describe individuals who have a predisposition to response to a particular chemical or exposure at levels that do not evoke the response in "most people." Usually, these individuals show susceptibility to specific chemicals, and have little susceptibility to other chemicals. The young, the old, the ill and those with genetic predispositions may display varying susceptibility to varying numbers of agents. Analysis of animal toxicity data for large groups of chemicals indicates that a 10-fold factor would yield an adequate reduction from the median response, but as humans are more heterogeneous than animals, the factor of 10 is not necessarily conservative.[22] Other research evaluating the variability of humans to metabolize substances typically support that the factor of 10 is protective. Thus, the standard default uncertainty factors assume that in the absence of data suggesting another factor, average humans are assumed to be ten-fold more sensitive than experimental animals. In the absence of data suggesting another factor, the most sensitive human will be assumed to be ten-fold more sensitive than the average human. Regarding occupational populations, The National Research Council (NRC) noted in 1994 that because they generally involve healthy adults, and do not include the most vulnerable segments of the general population, they are likely to display less variability in response to hazardous agents than the general population.[23] Likewise, deployed forces do not contain children, the infirm, and individuals with debilitating health conditions. This is interpreted to mean that deployed forces are not only less sensitive and vulnerable to the adverse effects of stressors in the environment, but that the range of variability in response is also likely to be much smaller than it is for the general population. This is the basis of the discussion as to whether or not AEGLs or RfCs are too conservative for deployed troops. Regardless of the validity of that claim, the Congress (in the Strom Thurmond Act, House Report, 1998) requested that "DOD should provide adequate protection of personnel from any low-level exposure to a chemical warfare agent at levels -even if not sufficient to endanger health immediately -are greater than is recognized as maximum safe level of exposure for the general population."

RISK ASSESSMENT MATRIX

SEVERITY	*PROBABILITY*				
	Frequent	Likely	Occasional	Seldom	Unlikely
Catastrophic	E	E	H	H	M
Critical	E	H	H	M	L
Marginal	H	M	M	L	L
Negligible	M	L	L	L	L

E- Extremely High Risk

H - High Risk

M- Moderate Risk

L- Low Risk

Figure 2-4, FM 100-14, Risk Management

Competing Risks and Risk Tolerance.

As the DOD plays the role of identifying health exposure criteria and implementing them, the process is often accompanied by intense external scrutiny, which might tend to encourage DOD to adopt conservative values. On the other hand, the Institute of Medicine (IOM) considered that conservative values might not be appropriate for deployed settings.[24] "When a high level of health and safety protection can be achieved without undue burdens or increases in other risks, such margins can be part of an effective risk management program. But when risks or probabilities of casualties must be weighted against immediate military considerations, best estimates of probable impact are more useful." While this is certainly a reasonable perspective, many of the current deployments are stability and support operations and the competing risks or immediate military considerations are minimized. In these settings, unevaluated or uncontrolled risks, or the acceptance of unnecessarily high risk would be less defensible. This is why operational risk management as a consistent tool is effective, in that it allows for at least a pseudo comparison of competing risks, and why a range of toxicity values representing a spectrum of risks is most useful. (Figure 2) The IOM panel acknowledged a need for operational risk management tools with utility to field commanders. They suggest a definition of risk that encompasses probability proposed by Kaplan and Garrick in 1981. For a deployment, the relevant components would be: 1) the likelihood of the presence of a hazard associated with a deployment, 2) the likelihood of releases of agents into the environment, given their presence, 3) the likelihood that troops will suffer exposure (of various magnitudes) given the releases, and 4) the likelihood that health effects will caused among them, given the exposure. The operational risk management framework currently used by commanders for all other threats adds an assessment of the severity of the health effects to characterize risk.[25]

Given that risk tolerance may differ with the scenario, in situations were competing risks are low, it would be desirable to protect troops from all unnecessary health risks to the degree feasible. The IOM identified modifications to the risk assessment paradigms for deployed troops, noting that deployed troops face a number of risks at once, and so the approach typically taken to address a single hazard is insufficient. Conceptually important is whether the threat is evaluated as a threat to individual service personnel while deployed, in cumulative career long and lifelong risk profiles, or as threats to the capabilities of whole military units or to the success of missions. Nonetheless, assuming that in some settings, the preferred goal is to maximally protect troops, we return to the question of whether or not the military requires different uncertainty factors addressing variability than does the general public: Are deployed forces less susceptible to adverse effects from exposures? Some changes in susceptibility that accompany circadian rhythmicity, for example, affect all individuals.[26] Factors affecting susceptibility may interact to increase or decrease the adverse affects of toxic exposures. They may be independent or interdependent. The factors that increase the susceptibility of the aged, for example, are often interdependent and include changes in nutritional status, exercise, medication and the functional reserve of all organs. Such susceptibilities would be most associated with segments of the population, although there is most likely a continuum of responses. Table 1 lists some factors that modify an individual's response to an exposure.

Table 1. Factors that Modify Individual Responses to an Exposure

Modifying Factor	Known or Probable Effect
Age	Susceptibility at age extremes
Gender	Variable
Smoking	Confers additive or synergistic risk
Alcohol Use	Increased susceptibility to hepatotoxins
Exercise at Time of Exposure	Increases exposure via inhalation
Family History	Hereditary conditions with increased susceptibility
Respiratory Disease	Diminished pulmonary reserve, increased reactivity or increased irritation
Atopy	Tendency towards sensitization
Asthma	Increased bronchial reactivity
Cardiovascular disease	Some exposures could precipitate angina
Seizure Disorder	May alter threshold
Dermatological condition	May lead to increased absorption
Renal insufficiency	Increased susceptibility to toxins excreted by the kidneys and renal toxins
Immune deficiency states	Increased susceptibility to toxins affecting the immune system
Infection	Increased susceptibility to bronchial irritation

Sources of Variability: Demographics

Age. The demographics of the active services differ from the general U.S. population.[27-28] Most obviously, the age range differs: the youngest troops are seventeen years of age, and roughly 40% of the population is below 25 years of age. Individuals younger than 25 years make up 35% of the U.S. population. The oldest service members are in the 60-65 year age group; this represents less than one percent of troops. In actuality, less than one percent of troops are above 50 years of age, compared with 28% of the U.S. population. The average age of a service member is between 25-29 years of age. With respect to the age of deployed troops, during the Persian Gulf conflict, 22% of troops were 35 years of age or above, which is similar to the percentage in this age group as a whole. Susceptibility to exposures is most pronounced at the two extreme of the life cycle. The fetus and infant are susceptible for a number of reasons to include the rapid rate of cell division, the large surface area relative to weight, immature detoxification processes, impaired renal excretion, and an immature immune system. Increased susceptibility to methyl mercury, lead, and nitrates, among others, has been demonstrated. The aging process can be identified at all levels of biological organization. Physiological change impairs the maintenance of homeostasis with age, as cardiac, renal, pulmonary and immune function decrease progressively with increasing age.[26] The aged are often able to function under resting conditions, but are less capable of withstanding environmental stress. They are more susceptible to infection, heat, and cold and exhibit a greater predisposition to toxicity of drugs, which would suggest an increased susceptibility to environmental chemicals metabolized in a similar fashion. This susceptibility may be related to impaired host defenses, body surfaces as portals of entry, possible changes in detoxification capabilities, impaired immune function, and impaired physiological functions. For the most part, the age range associated with military service does not contain the most susceptible subgroups of the population based on age.

Sex. Currently, about 15% of service members are female; during the PG conflict, less than 7% of those deployed were female. This sex distribution is markedly different from the U.S population as a whole, where the distribution between males and females is approximately 50/50.[27-28] The IOM recently reported that females and males have differences at the cellular level, which are manifested in differences in reaction to and metabolism of drugs. Male-female differences in response to toxic exposures in the environment have been demonstrated for benzene, lead and cigarette smoke, as well as nerve agents.[26] Females are more susceptible to the effects of exposure to benzene and nerve agents, while men are more susceptible to the effects of cigarette smoking. Thus, the difference in sex distribution may make the military population more or less sensitive, depending on the exposure. The deployed population is supposed to exclude one

susceptible population: pregnant females. The IOM notes that although pregnant women are not deployable, deployed women must have the means to detect pregnancy while deployed and policies for evacuation or movement of pregnant personnel out of the risk area must be developed, clearly understood and strictly enforced.[29] Field duty is restricted after 20 weeks.

Race/Genetic Traits. With respect to racial origin depending on the branch of service in question, 58-74 of service members are white, whereas 71 % of the general population is white. Approximately 15-25% are black, non-Hispanic, in contrast to 11% of the general population, and 8-13% are Hispanic, versus 11 % of the general population. Race is linked to differing susceptibilities to exposures or drugs, likely linked to genetic variation. For example, susceptibility to the antimalarial drug primaquine has been demonstrated due to G6PD deficiency leading to hemolysis of red blood cells. Although there a number of variants, the milder form is found in about 12% of African American males, and the more severe forms more common in those of Mediterranean descent. There have been a number of indications that such individuals are more susceptible when exposed to oxidizing chemicals as well.[26] Although antimalarials are often prescribed for soldiers traveling to malaria endemic regions, not all services screen for deficiency. Thus, in this example, the services may contain unrecognized susceptible populations.
Sickle cell anemia is a genetic disease that causes the red blood cells to sickle or collapse at low oxygen pressures, making it difficult for them to pass thru blood vessels normally, causing pain and tissue damage. Approximately 0.2% of African Americans have sickle cell disease. 8% of African Americans have sickle cell trait, as compared with 0.08% of non-African Americans. Additionally, there is variable prevalence of disease and trait in different ethnic groups, and appearance or ethnic group is not a sensitive indicator of status.[30] Most individuals with sickle cell trait are not aware that they have it as they typically lead normal lives, but problems may occur under unique or stressful conditions producing severe hypoxia such as flying in unpressurized planes. In 1968, four recruits who were trait positive died while training at elevations above 4060 feet.[31] In 1969, the Navy established policy to test all recruits. In the 1970's, operational restrictions were placed on those who were sickle cell trait positive to prohibit their participation in activities that would place them at risk such as aviation, diving, Special Forces and high altitude parachuting. In 1981, the DOD set a cut-point of > 41% HgS for restrictions. In 1985, DOD policy removed all restrictions related to sickle cell trait.[32] In the mid 1990's, three deaths in trait positive recruits under conditions of heat stress. In 1996 the Armed Forces Epidemiology Board recommended increased heat injury prevention measures and continued research.[33] The Army screened only high-risk occupations, although trait positives are not disqualified, and the other three services screen all accessions. Individuals who are trait positive are counseled regarding risks. Recently, five deaths in soldiers under conditions of exertion have led to a change in Army policy to introduce universal screening of recruits. This is another example of a genetically based susceptibility with a rather severe possible endpoint hat is relatively prevalent in the military population. With regards to metabolism of foreign substances such as drugs and chemicals, a phenotype known as "slow acetylators" has been identified. It was noted that there are individuals who acetylate the antituberculous drug isoniazid slowly, leading to prolonged excretion.[26] The blood levels of drug in these patients are higher and they are more prone to toxic reactions. Population studies indicate that 60% of Caucasians and African Americans and 10% of Asians are slow acetylators. Slow acetylation and delays in excretion may be important in the metabolism of chemicals such as arylamines, and may be relevant in the carcinogenesis of bladder carcinogens of this class. Similarly, the cytochrome P450 containing mixed function oxidase system metabolizes many substances. It has been shown that one of these, the aryl hydrocarbon hydroxylase, can be induced to increase activity following exposure to polycyclic aromatic hydrocarbons and insecticides. Increased activity in the instance of PAHs is not beneficial, but results in the formation of carcinogens. Inducible forms of aryl hydrocarbon hydroxylase are found in about 1 in 10 individuals in the U.S. Genetic variability has also been suspected due to hypersensitivity of some members of the population to beryllium. Chronic beryllium disease had occurred in some individuals not occupationally exposed at very low levels. It has been postulated that several alleles affecting sensitivity to beryllium may exist and sensitivity increases as the number of alleles possessed increases. Thus, discrete groups may exist with differing sensitivities, rather than a single continuous dose-response relationship. One allele has been identified in 90% of those with the disease. However, it is also present in 30% of the general population.[34] Therefore, susceptibility is highly linked with getting the disease, but a large portion of the population is at risk. Further, the prevalence of chronic beryllium disease in women is estimated to be six-fold higher than in men. In this particular example, susceptibility is not necessarily restricted to small fractions of the population. Genetic polymorphism was

demonstrated when a soldier demonstrated severe symptoms following pyridostigmine bromide prophylaxis during the Gulf War. He was determined to be homozygous for atypical BuChE. Homozygotes can be present in up to 1% of some population groups. The serum BuChE in homozygotes has much less binding affinity or sensitivity toward PB and other anit-ChE's.[35] Intraspecies variation has also been demonstrated in blood cholinesterase activity, which may affect susceptibility to the toxic effects of nerve agents. Homozygous individuals have plasma ChE activity reduced to less than 25% of normal values, whereas heterozygous individuals have ChE levels about 64% of normal. [36-38] Heterozygotes represent about 3% of the population.[39] Plasma ChE activity may also be depressed in young children and pregnant females as well.

Table 2. Genetic Factors and Susceptibility to Chemicals[a]

Predisposing Factor	Incidence	Chemicals	**Environmental interaction?**
Glucose-6-phosphate dehydrogenase deficiency	12% in African American males	Oxidizing Chemicals	Likely
Sickle Cell Trait	7-13% in African Americans	CO, aromatic amino compounds	No clear evidence
Methemoglobin reductase deficiency	1% population heterzygotes	Nitrites, aniline	Definite
Aryl hydrocarbon hydroxylase induction	High-induction type Caucasians about 30%	Polycyclic aromatic hydrocarbons	Possible
Slow acetylator phenotype	60% Caucasian and Black populations	Aromatic amine induced cancer	Possible
Immunologic hypersensitivity	Unknown, 2% in some occupational populations	Isocyanates	Definite
Paraoxonase variant	50 % in Caucasians, Asians about 30%, blacks about 10%	Parathion	Possible

a. *From Tarcher, Principles and Practice of Environmental Medicine*[26]

Table 2 provides these and other exa mples of genetic variants that can affect susceptibility to environmental exposures. Many of these are found in significant fractions of the general population and are not identified by screening prior to military accession. Thus, with respect to these s usceptibilities, the military or deployed population cannot be considered less susceptible than the general population. The human genome project has determined that 99.9% of the genome is identical for all persons with variation representing 0.1%. As this 0.1% is explored, it has been proposed that careful phenotyping could identify disease risk associations within the next 5-7 years. As this progresses, previously unrecognized genetic variability may be identified, but the role of environmental factors will also need to be considered. For example, asthma appears to have genetic variations that may determine susceptibility, but environmental factors may precipitate the actual disease. Increasingly, as we learn more about human variability, and its interactions with exposures, stress or hormonal differences, it may be possible to identify susceptible individuals. However, susceptibility is most often not immediately obvious, and may not be detectable without sophisticated testing. Such testing is obviously not currently performed in service members.

General Health in the Deployed Population.
Similar to the healthy worker assumption discussed previously, there is a general assumption that the service members are healthier than the general population, as there are standards of fitness required for military accession and retention. Examination is required on entry to the service to ensure that recruits are free of infectious disease, and conditions or defects which would require "excessive time lost from duty or would likely result in separation from the service for medical unfitness." [40] They also need to be adaptable to the military environment without unnecessary geographical limitations and able to perform duties without aggravation of existing physical defects. Recruits can be disqualified due to the presence of a number of conditions: the most common are hearing loss, vision deficiency, asthma, hypertension, flat feet, musculoskeletal and knee derangements, psoriasis, cardiovascular disease, diabetes and some bone conditions. About three percent of all recruits present with these conditions but receive a waiver. Therefore, although individuals with these conditions may be screened out, many are not, depending on medical judgement. Further, if the recruit does not disclose the presence of a condition not evident on examination, accession would not be blocked. At the time of accession, then, the active duty force would be considered "healthier" than the general population. It is not clear, however, that conditions that make one more sensitive or susceptible to the effects of exposures are the conditions that are identified and disqualify one. Further, many individuals can develop a disease or condition while on active duty, but may not be discharged because of it. The physical conditioning of U.S. forces prior to deployment has generally never been better.[29] Active-duty forces are maintained in excellent physical and dental health. However, the trend in downsizing the standing forces and relying on the National Guard and Reserve Forces changes the fitness and age profile of the deploying force. For example, 17% of forces deployed in support of the Persian Gulf War were reserve component members. Reserve component members tend to be older on average, and may have more general health and fitness issues than the active force. Additionally, an increasing proportion of deployments now include coalition forces and the composition of those forces is quite heterogeneous and often different from U.S. forces Increasing use and dependence upon DOD contractor personnel will require an assessment of the characteristics of these additional personnel such as age, health status, fitness, past medical treatment and records, training proficiency, and possible stress level associated with separation.

Lifestyle Factors and Coexisting Exposures
Susceptibility to environmental exposures can be affected by exposure to other toxic chemicals. Individuals may thus have increased susceptibility on the basis of occupation and lifestyle-related exposures. The best example of this increased susceptibility is the increased risk for lung cancer in smokers exposed to asbestos. The risk of lung cancer is increased by a factor of five for those exposed to asbestos versus those not, and by a factor of ten for those who smoke versus those who do not. However, when an individual is exposed to cigarette smoke and asbestos, the risk rises to 50 times that of unexposed individuals. [41] This phenomenon is known as synergistic interaction. The prevalence of smoking is currently approximately 30% in the military as compared with about 22% in the general population.

Coexistence of Disease.
Many disease processes make an individual more susceptible to the effects of environmental toxicants. Asthma and other pulmonary conditions would increase susceptibility to airborne pollutants; liver disease might increase the susceptibility to toxicants metabolized by the liver. While asthma has a prevalence of 4-6% in the general U.S. population, service applicants are disqualified if they give a history of asthma. The portion of the physical examination that would identify the presence of asthma is auscultation of the lungs, not a particularly sensitive test, and individuals might not reveal their conditions. In the past five years, 6% of applicants were disqualified due to disorders of the lungs and chest, the third most common cause behind weight and cannabis use as a reason for disqualification.[42] However, the Army, Navy and Marines will grant a waiver if the individual has been symptomatic since age 12. One recent small-scale evaluation indicated that up to 4% of individuals might receive waivers for asthma. Asthma has been the top disease or disorder for which waivers have been granted for the past three years. Additionally, individuals may develop asthma while on active duty or fail to disclose a history of asthma. During periodic physicals, soldiers found to have asthma are not necessarily discharged. Referral for a medical evaluation board occurs when asthma persists greater than six months or requires the use of medications to perform all military training duties. Even so, such individuals may be given a temporary profile for one year. During the past four years, about 15% of early discharges are for asthma.[42] Asthma ranks thirty-ninth when

conditions requiring medical encounters in the military are ranked, and 44th in terms of numbers of individuals affected.[43] Therefore, while the military has a lower prevalence of asthma than the general population, as well as other respiratory conditions such as emphysema and chronic bronchitis, it is not a safe assumption that no asthmatics will be deployed, nor that all individuals who may be more sensitive to the effects of air pollution or irritants, for example, will be excluded from deployment. Indeed, asthma was one of the major causes for evacuation out of theatre during the Persian Gulf conflict.

Skin disorders represent a common condition seen in the military. Although individuals may be disqualified if presenting with severe psoriasis or other conditions at accession, skin disease is very common in service members. Skin conditions rank 10th in terms of the reason for medical encounters, and represent 10-20% of outpatient medical encounters. [43] Most skin conditions that are diagnosed during service do not require evaluation for discharge unless they interfere with duties or wearing of the uniform. Skin disease may increase the sensitivity of an individual to exposures, particularly by the dermal route, due to breaks in the skin integrity.

Asthma and skin conditions might be uncovered by observation or history at the time of exam, but not all conditions are apparent in this manner. For example, liver disease would likely interfere with the metabolism of some xenobiotics, but sub-clinical disease might exist and be apparent only if liver function tests are performed. There are a number of tests ordered as part of the physical examination. Some are specific to certain diseases whereas others are not. Tests currently performed as part of the physical are noted in Table 3. While some conditions such as diabetes or high cholesterol (hyperlipidemia) may be detected, liver and renal function are not specifically evaluated, nor are many other specific diseases which might interfere with the metabolism of contaminants which enter the body, or increase one's susceptibility to an adverse outcome from an exposure.

Required Testing as Part of the Physical Examination Process

Test	Target organ or conditions
Cholesterol	Hyperlipidemia
HIV Test	HIV infection
Stool Guiac	Gastrointestinal bleeding
Urine microscopy	Cells, infection
Urine Specific Gravity	Evaluates hydration, fluid regulation
Fasting Blood Sugar	Diabetes
Chest Xray	Lung lesions, etc
Syphilis Test	Syphilis
Pregnancy Test	Females only at accession
Hemoglobin/hematocrit	Anemia
Sickle Cell Test	Only for Special Forces, combat diving
G6PD	G6PD deficiency, only for combat diving

Adequacy of Uncertainty Factors for Various Chemicals.

Although in the classic risk assessment process, an uncertainty factor of ten is the default value, for some chemicals, the intra-species variability is addressed utilizing an uncertainty factor of three versus ten. This is because the effect under concern is considered local, and the substance is direct acting and doesn't require metabolic conversion.[44 a] factor of ten has been has been estimated to address 80% of variability in the ability to metabolize foreign substances.[21] when the effect of concern is irritation, intra-species variability is not considered to be large. Ideally, sufficient data would exist to document the appropriate uncertainty factor, rather than utilizing the default value of 10. This would obviously limit conservatism. In the recent AEGL proposals published in the Federal Register (May 2001), of the 18 chemicals, an uncertainty factor of 3 was used in 2/3 of the derivations.[45] Insufficient data was available for some chemicals to use three, or the variability factor of ten was supported by available data in the rest of the

instances, except for a UF of zero used for the carbon monoxide value. This was due to the selection of an exquisitely sensitive population (those with heart disease) in the critical study. For this specific chemical, the value based on that endpoint might be too conservative for a deployed population that should be expected to have a lower prevalence of heart disease. However, given the considerations in the derivation of the other values, it cannot be concluded that such values are "too conservative" for deployed troops on the basis of the interspecies variability uncertainty factor.

The IOM noted that "deployed forces can be expected to vary greatly in age, ethnicity, genetic susceptibilities and prior histories of exposures to toxicants and disease, as well as in possible allergic or stress reactions to exposures or countermeasures." Additionally, the deployed military population is subject to a variety of battle-related risks, including those related to chemical and biological warfare agents, and additional risks of infectious disease, exposure to chemical contaminants in air, water, food, and soil and a variety of physical threats, including those associated with accidents and explosions and with certain forms of ionizing radiation, and with excessive heat, cold and noise. Medical treatments designed to protect forces from risks may pose other health threats.[24] With respect to the deployment to the Persian Gulf, the IOM noted that "Service personnel were exposed to an extraordinary array of environmental conditions. Their complex experiences combined to yield what is a truly varied and sometimes confusing picture of exposure that has proven difficult to understand, much less reconstruct."[29,46] Forces might be exposed to these conditions intermittently, continuously, or simultaneously. Furthermore, the deployed population might have greater opportunity for exposure based on their activity patterns, resulting in greater internal doses received. Weight for weight air or soil concentrations assume certain default parameters for exposed skin, inhalation rate, etc. Dermal exposures can be significant during field exercises and combat situations, and inhalation doses can be greatly affected by the amount of air inhaled, the frequency of respiration and the depth of penetration of the air inhaled into the lungs.[24]

These factors create a complex environment that is difficult to summarize and quantify in risk assessment with a single value. Individual, situational, geographical and cumulative factors may influence susceptibility. Assessing susceptibility to toxic exposures requires a highly individualized approach, difficult to translate to heterogeneous situations and populations. The statement that deployed military populations are less susceptible to exposures than the general population is simplistic and deserves further study.

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